16^{TH} EUROPEAN CONCURRENT ENGINEERING CONFERENCE 2009

ECEC'2009

6^{th} FUTURE BUSINESS TECHNOLOGY CONFERENCE

FUBUTEC'2009

EDITED BY

Hendrik Van Landeghem

and

Danny Van Welden

APRIL 15-17, 2009

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PREFACE

As we live through these financially trying times research in Concurrent Engineering and Business Technology are becoming more and more relevant in streamlining and optimizing production techniques on the one hand and risk management on the other, while limiting the actual risk of producing and financing innovation.

The present day world and its economic and business turmoil show that incremental testing of the many different paradigms, one against the other, is an economic must and leaves researchers worldwide no other option than the intelligent adaptation of these solutions and concepts that fit within the contours of the new reality in order to thrive in the aforementioned reality.

Concurrent Engineering has shown itself to be an excellent tool for improving the efficiency of industrial and business processes, supported by an intelligent and creative utilization of technological advances. This together with its offspring in GRID and cloud computing is proving to be the way forward for solving future challenges.

While on the other hand intelligent multimedia data-mining is lying at the basis of the foundation of a new field called surprise modeling. Something we will hear about more and more in the future and which will influence our lives in the years to come.

These two conferences (ECEC-FUBUTEC) aim mainly at bringing together those, who around the world research these matters, in order to promote the spread of knowledge to the global community. We hope that this meeting will also contribute to a better visibility of these subjects and introduce others to their importance.

Although this conference has been the result of the work of several personalities, we would like specially to mention the dedication of the committee members, input of the authors and the fundamental contribution of Mr Philippe Geril, for the excellent organization that allowed this conference to be held in Bruges. We would also like to refer to the support given for this event by the department of Industrial Management of Ghent University and by KBC.

We finally hope, you have an agreeable working experience during these couple of days, and an exciting stay in Bruges, the Venice of the North.

The ECEC-FUBUTEC chairmen,

Hendrik Van Landeghem

Danny Van Welden

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LARGE SYSTEM SIMULATION

APPLICATION OF A DECISION SUPPORT SYSTEM IN MANAGING TIMBER PRODUCTION IN NORTH OF IRAN

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KEYWORDS
Decision Support System, Timber Production, Regeneration Method, Future Species Mixture

ABSTRACT

The application of a decision support system (DSS) for selecting the best silvicultural treatment option in Iranian northern forests is presented. The DSS developed by Harald Vacik and Manfred J. Lexer was used. The decision problem is factorized into decisions on the future species mixture (GSO) and on an appropriate regeneration method (RM). A priori defined sets of alternatives (five species mixtures, six regeneration methods) are evaluated with respect to a set of stand-specific partial management objectives (timber production, conservation of biodiversity, recreation, protection against rock fall and avalanches) by further decomposing the partial objectives into decision criteria. An additive multiple-attribute preference model is used to aggregate the preferences at different levels of the decision hierarchy. The combination of GSO and RM which simultaneously maximizes the expected utility and satisfies all constraints of the forest decision maker is selected as the overall best solution. Finally, a species mixture of Fagus orientalis., Acer insigne, Quercus castanefolia (GSO5) was considered to yield the highest utility with respect to a multiple-purpose management, with the main objective to secure the sustainable yield of timber production. With respect to the goal types, the most preferred regeneration systems were selection forest and strip-and-group selection.

INTRODUCTION

Forest industries as such belong to the basic, strategic industries in the world. Forest industries operate worldwide. the last decade or so has seen a large emphasis on 'sustainable development', where it has become important to take out less than is being grown, and with the same mixture of species that was there before. In recent years, emphasis in forest management planning is being placed not only on timber production but also on values, such as recreation, wildlife and amenities. In the mountainous terrain of Iran, forests provide protection against soil erosion and natural hazards, such as avalanches and rock fall and, thus, play an irreplaceable role in the maintenance of Alborz landscapes. Considering the complexity of silvicultural decision problems within multiple-purpose forestry with many site and stand attributes, neither intuitive nor schematic solutions are appropriate planning approaches. According to Keeney and Raiffa (1993), four phases of decision analysis can be distinguished: (1) structuring the decision problem, (2) assessing the impacts of each possible solution, (3) determining the preferences of the decision maker and (4) comparing the decision alternatives. The planning process should be understandable and pedagogical, so that all the participants can fully understand the reasoning and results. Unfortunately, practical MCDS(Mult Criteria Decision Supprt) applications are often too technically oriented, and either over-simplify reality or are too difficult to use, understand, and interpret (e.g., Corner and Buchanan, 1997). Some recent studies indicate that it would be useful to utilize more than just one MCDS method or hybrid approach in many planning situations, especially for behavioral reasons (e.g., Bell et al., 2001; Belton and Stewart, 2001; Kangas et al., 2001a). In general terms, DSS are computer-based systems for integrating data base management systems with analytical and operational research models, graphic display, tabular reporting capabilities and the expert knowledge of decision makers to assist in solving specific problems (Fischer et al., 1996). In many silvicultural decision problems, such as the choice of regeneration methods (RMs), information at spatial scales beyond the stand level is needed (e.g. Mayer, 1984; Burschel and Huss, 1997). Increasing uncertainties with respect to changing environmental conditions and a steadily increasing amount of information on the management of forest ecosystems have caused a growing interest in decision support for silvicultural planning at the stand level (e.g. Mueller, 1997). In contrast to these needs, most of the available planning models support long-term strategic harvest scheduling problems at the forest level rather than site- and stand-specific silvicultural operations (Davis and Martell, 1993). To support silvicultural planning at the stand level in the protection northern forests of Iran, a spatial decision support system that developed by Harald Vacik and Manfred J. Lexer (2001), was used. They developed an applied a spatial decision support system for managing the protection forests of Vienna for sustained yield of water resources.

MATERIALS & METHODS

The DSS developed by Harald Vacik and Manfred J. Lexer was used in this study. The protection northern forests of Iran were selected as test site to demonstrate the application of SDSS-methodology for the multiple-objective management of forests where objectives other than timber production are concern. Different objectives are timber production, protection against rock fall and avalanches as well as recreation and conservation of biodiversity values (Anon., 1973).

The forest management unit comprises 1546 ha of forest land and is located 800 and 1700 m a.s.l. The Hyrcanian forests comprise a little more than 2.1 million hectares of almost 100 percent hardwoods, primarily beech (Fagus orientalis) and hornbeam (Carpinus betulus). Other marketable species include maple (Acer insigne), oak (Quercus castanefolia), alder (Alnus subcordata), elm (Ulmus glabra), ash (Fraxinus excelsior), and iron wood (Parrotia persica). The small percentage of softwoods include cypress (Cupresuss sempervirens), juniper (Juniperus polycarpos), and yew (Taxus bacata). Recent defnitions (e.g. Densham, 1991) suggest that spatial decision support systems have the following distinguishing characteristics:

1)they are designed to solve ill-structured problems, 2)they have a user-interface that is both powerful and easy to use, 3)they enable the user to combine data and models/ methods in a flexible manner, 4)they help the user to evaluate the decision space/ the available options, 5)they can be adapted to specific situations, 6)they provide mechanisms and tools for the input and storage of spatial data, 7)include techniques for spatial analysis and query, 8)provide output in spatial forms

For entering, processing, and storage of spatial information, geographical information systems (GIS) are required (Burrough and McDonnell, 1998). The analysis of spatial data is greatly enhanced by the integration of MapModels (Riedl and Kalasek, 1998), a flow-chart based programming routine. However, the expectation that all involved applications are fully integrated and relevant components of the decision model can be modified by the decision maker.

STRUCTURING THE DECISION PROBLEM

Prior to any application of decision support tools, the decision maker has to structure the decision problem at hand. According to the management guidelines (Anon., 1973; Fischer, 1997) the general management objectives for the protection forests of northern Iran are to ensure the sustained yield of timber production, protection against rock fall and avalanches as well as recreation and conservation of biodiversity. As an a priori principle, it is stated explicitly that these objectives shall be achieved by favoring mixed-species multi-cohort stands where the species composition has to be closely related to the potential natural vegetation (Fischer, 1997). Silvicultural planning requires selecting a solution which most probably maximizes the overall utility with respect to the management objectives. In our example, we focus on stands which had been scheduled for regeneration harvest. Decision making about naturally regenerating a stand requires the consideration of three sub-processes: determining when to begin the regeneration process, choice of the future species composition (growing-stock objective), and selection of the RM. In this example, it is assumed that the decision about the time of regeneration already has been made. Thus, the following questions had to be answered for each stand:

1) What are the management objectives for the particular stand? 2) Which future species composition is most suitable with respect to the management objectives? 3) Which regeneration method is most suitable with respect to the management objectives? 4) What is the solution which maximizes overall utility with respect to the management objectives and simultaneously satisfies the constraints?

By means of a set of decision rules, each stand was assigned to one of eight different goal types based on site characteristics (slope, soil type), spatial relationships (proximity to forest roads/settlements/viewpoints/scenic locations), and site index class. For each goal type, the forest manager had to determine the relative importance of the objectives (Table 1).

Table 1: Relative Importance of Partial Objectives for the Multi-Purpose Management of the Protection Forest of Northern Iran

Goal type	Timber production	Recreation	Protection	Biodiversity conservation
1111	0.340	0.041	0.423	0.259
1110	0.210	0.012	0.216	0.193
1101	0.132	0.072	0.221	0.123
1100	0.521	0.011	0.541	0.2846
1011	0.290	0.032	0.361	0.143
1010	0.364	X	0.326	0.324

Six different species composition targets or growing-stock objectives (Table 2) which were feasible from a silvicultural point of view had been defined based on the set of tree species occurring in the regional associations of the potential natural vegetation (PNV) As a prerequisite for the selection of a future species composition, the suitability of tree species for a particular site had to be determined. To accomplish this task, a simplified version of a static suitability model as presented by Steiner and Lexer (1998) was adopted. Systems of stand regeneration which a priori were considered to be potentially applicable were (a) clear-cutting, (b) shelter wood, (c) shelter wood group selection, (d) strip, (e) strip-shelter wood, (f) strip-and-group and (g) selection forest. Evaluating the growing-stock objectives (GSO) as well as the RM with respect to the stand specific management objectives is a complex multi-criteria problem where as a first step, appropriate evaluation criteria have to be selected. More-over, a possible trade-off between advantages and disadvantages of a particular GSO and a particular RM to implement this GSO has to be considered to allow for the selection of the solution with maximum overall utility. Both the physiological suitability of a GSO as well as the possibility to implement a GSO with a particular RM were used as constraints in the decision model.

Table 2: The Set of Growing-Stock Objectives (GSO) for the Protection Forests of Northern Iran Mixture Type

Mixture Type	Species Proportions in Percent (%)
GSO1	Fagus orientalis (75), Carpinus betulus (25)
GSO2	Fagus orientalis (65), Acer insigne (35)
GSO3	Fagus orientalis (70), Quercus castanefolia (30)
GSO4	Carpinus betulus. (50), Parrotia persica (50)
GSO5	Fagus orientalis. (50), Acer insigne (L.) (30), Quercus castanefolia. (20)
GSO6	Parrotia persica. (60), Quercus castanefolia (20), Parrotia persica. (20)

To evaluate the overall utility of decision alternatives in case more than one possible solution exists, an approach that borrows from multiple-attribute utility theory (MAUT) was adopted. This method requires the mathematical characterization of the preferences of the decision maker over a set of attributes (Goicoechea et al., 1982). Overall utility of a silvicultural alternative is composed of partial utilities which are obtained from selecting a particular GSO and a RM, respectively. The expected utility can be seen as a measure of how well an alternative meets the objectives with respect to the preferences of the decision maker (Mollaghasemi and Pet-Edwards, 1997). The general form of the utility function can be written as:

$$U = aU_{GSO} +. bU_{RM} \quad (1)$$

Under the constraint that $(a+.b.=1)$ and where

$$U_{GSO} .= a_{1v}P_{WPGSO} .+ a_{2v}P_{TPGSO} .+ a_{3v}P_{RCGSO} +. a_{4v}P_{PTGSO} .+ a_{5v}P_{BDGSO} \quad (2)$$

$$U_{RM} .= b_{1w}P_{WPRM} +. b_{2w}P_{TPRM} +. b_{3w}P_{RCRM} .+ b_{4w}P_{PTRM} .+ b_{5w}P_{BDRM} \quad (3)$$

And Equations (4a) and (4b):

$$\sum_{s=1}^{5} a_{sv} = 1$$

$$\sum_{r=1}^{5} b_{rw} = 1$$

The partial utilities U_{GSO} (2) and URM (3) are composed of additively aggregated preferences for a particular GSO and RM with respect to the involved management objectives where the parameters asv and brw characterize the relative importance of the partial objectives timber production (PTP), recreation values (PRC), protection against rock fall and avalanches (PPT) and conservation of biodiversity (PBD). However, the utility of a silvicultural alternative is difficult to express in quantitative terms. For instance, forest growth models could be employed to project stand growth according to the assumptions of a decision alternative. The obtained net present value (NPV) from a treatment alternative could then be used to quantify the utility with respect to timber production (Pukkala and Kangas, 1993).

RESULT & DISCUSSIONS

As a preliminary step in applying the decision model to stands in the forest management unit, the expected utilities from the GSOs and the RMs were calculated for the stand-level goal types. To identify the overall best solution for a stand, an appropriate RM had to be combined with a GSO suitable for the site conditions in the pertinent stand. In selecting a RM and GSO, respectively, the decision maker is constrained by the species site requirements and by the applicability of a RM with respect to stand attributes and tree species characteristics. For stand no. 12b1 (goal type 1100), the solution with the highest expected utility was a combination of GSO3 and RM4.

Other possible solutions for stand no. 12b1 are sorted in descending order with respect to overall utility. In general, a species mixture of Fagus orientalis, Acer insigne, Quercus castanefolia (GSO5) was considered to yield the highest utility with respect to a multiple-purpose management, with the main objective to secure the sustainable yield of timber production. With respect to the goal types, the most preferred regeneration systems were selection forest and strip-and-group selection. An important feature of a SDSS is the possibility to test the applied decision model for sensitivity to changes in specific model assumptions. The decision model partitions the complex decision problem into partial problems which are considered independently. By decomposing the originally ill-structured decision problem into decisions on future species mixtures (GSO) and RM, structural clarity could be increased. In the design of the decision space, the constraints given by the forest owner reduced the number of alternatives for GSO and RM substantially. The trade-off between a preferable future species mixture (GSO) and an applicable RM is modeled by means of an additive multiple-attribute preference model. One of the advantages of the presented preference model is that value judgments at the level of objectives and partial objectives are clearly separated from the weighting of criteria and the evaluation of alternatives. As with any model there are several problems involved with the presented approach that the user should be aware of. It is important to note, that with the AHP, the set of alternatives is confined to a maximum of 10 (Saaty, 1996). However, this should not be a serious issue for most silvicultural decision problems. A further important feature of Saaty's method is the possible occurrence of rank reversals if additional alternatives are added. Thus, the method is not directly applicable to decision problems where the set of alternatives under evaluation is not equivalent with the total decision space. In other words, the current set of alternatives can not be embedded in a larger set of alternatives (Schneeweiû, 1991). The latter point should be emphasized to make the decision maker aware of the fact that his preferences strongly determine the outcome of the evaluation process. Sensitivity analysis is one of the powerful tools of decision support systems. A useful approach could be the development of a model base management system which stores model components in an object-oriented data base (Densham, 1991). The integration of spatial information and stand and site specific attributes was considered to be inevitable. Geographic information systems provide powerful tools to retrieve and visualize spatial information to prepare the ground for the design of decision alternatives.

REFERENCES

Davis, R.G., Martell, D.L., 1993. "A decision support system that links short-term silvicultural operating plans with long-term forest level strategic plans". *Can. J. For. Res*. 23, 1078-1095.

Fischer, M.M., Scholten H.J., Unwin, D., 1996. "Geographic information systems, spatial data analysis and spatial modeling". In: Fischer, M.M, Scholten, H.J., Unwin, D. (Eds.), Spatial Analytical Perspectives on GIS. *GISDATA Series No. 4 Taylor and Francis*, London, pp. 3-19.

Goicoechea, A., Hansen, D.R., Duckstein, L., 1982. "Multi-objective Decision Analysis with Engineering and Business Applications". *Wiley*, New York.

Harald Vacik, Manfred J. Lexer, 2001. "Application of a spatial decision support system in managing the protection forests of Vienna for sustained yield of water resources". *Forest Ecology and Management* 143 (2001) 65-76

Howard, A.F., 1991. "A critical look at multiple criteria decision making techniques with reference to forestry applications". J. For. Res. 21, 1649-1659. Hwang, C.L., Yoon, K., 1981. "Multiple attribute decision making methods and applications". *A state-of-the-art survey. Lecture Notes in Economics and Mathematical Systems*, Vol. 186. Springer, New York.

Kangas, J., 1993. "A multi-attribute preference model for evaluating the reforestation chain alternatives of a forest stand". *For. Ecol. Manage*. 59, 271-288.

Kangas, J., Kuusipalo, J., 1993. Integrating biodiversity into forest management planning and decision making. For. Ecol. Manage. 61, 1-15.

Keeney, R.L., Raiffa, H., 1993. "Decisions with Multiple Objectives: Preferences and Value Tradeoffs". Cambridge University Press, New York.

Lexer, M.J., Vacik, H., Hoenninger, K., Unegg, F., 2000. "Implementing a decision support system for silvicultural decision making in low-elevation Norway spruce forests". In: *EFI Proceedings of the International Workshop on Spruce Monocultures in Central Europe .Problems and Prospects*, 22-25 June 1998, Brno, Czech Republic (in press).

Mendoza, G.A., Sprouse, W., 1989. "Forest planning and decision making under fuzzy environments: an overview and illustrations". *For. Sci*. 35, 48 1-502.

Nñsset, E., 1997. "A spatial decision support system for long-term forest management plan by means of linear programming and a geographical information system". *Scand. J. For. Res*. 12, 77-88.

Pukkala, T., Kangas, J., 1993. "A heuristic optimization method for forest planning and decision making". *Scand. J. For. Res*. 8, 560-570.

Rauscher, M.H., 1999. "Ecosystem management decision support for federal forests in the United States": *a review. For. Eco*. 114, 173-197.

Riedl, L., Vacik, H., Kalasek, R., 2000. "Map Models: a new approach for spatial decision support in silvicultural decision making". In: *Proceedings of the International Conference on the Application of Scientific Knowledge to Decision Making In Managing Forest Ecosystems*, 3-7 May 1999, Asheville, NC. Computers and Electronics in Agriculture 27 (1-3), 407-412.

Tecle, A., Fogel, M.M., Duckstein, L., 1988. "Multi criterion analysis of forest watershed management alternatives" *Water Resour. Bull*. 24 (6), 1169-1 178.

SYSTEM DYNAMICS MODELLING OF AN NAUTICAL TOURIST BUSINESS SYSTEM (NTBS)

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KEYWORDS

Simulation modelling, business system of nautical and tourist ports, investments in sports objects, competitive advantages,, sports and recreation market.

ABSTRACT

System dynamics simulation modelling of a nautical and tourist port NTBS (Nautical Tourist Business System) in relation to investments in sports objects will result in an increase of the quality of the total offer and an increase of competitive forces of the observed system. The system of nautical and tourist ports NTBS has all the characteristics of a complex organisation and business system, for which dynamic modelling efficient methods of simulation techniques have to be used.

In this paper, the NTBS will be determined through a global model of integral nautical and tourist service (from berthing service as a basic service to all other additional services). The subsystem of investments in new capacities, like sports and additional capacities will be determined by exogenous variable **VINK** – value of investments in new capacities.
Remark: This is the work of the National Science Project "Maritime shipping travel in function sustainable development" label: 250-0000000 -1452.

SYSTEM DYNAMICS QUALITY SIMULATION MODELS OF A NAUTICAL TOURIST BUSINESS SYSTEM

The subsystem of investment in sports objects of a business system of a nautical and tourist port must have the characteristics of intelligent behaviour, which implies the following characteristics of managing behaviour: "If the capacity of NTBS is full and if in the last several years the income per guest has not increased, it is necessary, in the next mid-term period, to invest in new facilities which will improve the quality of the total services of NTBS.
In this case it is planned to build at least 4 outdoor and two indoor tennis courts, one beach volleyball court and one swimming pool of $50m^2$, including facilities like dressing rooms, sauna, showers, massage and medical assistance, etc.). In case there is a decline of interest in the main NTBS services, berthing, then it is necessary to stop the construction of new capacities. This implies that the started objects will be finished, while the others will be built after the demand increases again. Also, if the state of the cash-flow account of NTBS is not positive or there are not sufficient means to

cover the investment, it is necessary to ensure the mid-term and long term loans in order to complete the investment."

In order to determine the global system dynamics simulation model of NTBS, it is necessary to determine the following relevant subsystems: subsystem of berthing capacity (the main nautical and tourist service); subsystem of servicing vessels; subsystem of capacities of additional services (trade and catering); information subsystem; subsystem of the state of cash-flow; subsystem of credits for performed services; subsystem of debts; subsystem of income; subsystem of marketing and sales; subsystem of long term and short term loans; subsystem of engagement of total capacities; subsystem of the new sport capacities and their facilities.

Simulation of NTBS begins on the first day of April of the observed business year (TIME=120 days). The first season finishes at the beginning of October of the same year (TIME=300 days). The next period of off-season business begins in October of the same year (TIME=300 days) and lasts to the beginning of the new season (TIME=485 days). The new tourist season begins on the 485th day (TIME=485 day) and lasts to October of the next business year (TIME=665 days). New off-season business begins on the 665th day and ends on the 850th day (TIME=850 days).
Investing into new capacities begins on the 380th day (TIME=380) and lasts on average 180 days, which means that it ends on the 560th day of business, and the first positive effects of the investment (variable KPNI), or increase of the total income (UP), total operating costs (UTP), generator of the vessel arrivals (GDP) and average realised revenues per vessel per day (POPPD) stars in time TIME=406 days.

MENTAL, VERBAL AND STRUCTURAL SYSTEM-DYNAMICS SIMULATION MODEL OF NTBS BUSINESS SYSTEM

In accordance with system dynamics simulation quality methodology, it is possible to present the mental and verbal model of LNT in the following way: "If the variable *generator of the vessel arrival* GDP increases, *the number of vessel registration a day* BPPD will also increase, which shows a positive (+) cause-effect connection UPV", i.e., as abbreviated**:** GDP(+)→(+)BPPD.
«If the *number of vessel registration a day* BPPD *increases, the total number of registered vessels* UBPP will also increase, which shows a positive (+) cause-effect connection UPV», i.e., as abbreviated**:** BPPD(+)→ (+)UBPP.
If the *total number of registered vessels* UBPP increases, *the number of vessel checkouts a day* BOPD will also increase, which shows a positive (+) UPV.", i.e., as abbreviated: UBPP(+)→ (+)BOPD.
"If the *number of vessel checkouts a day* BOPD increases, *the total number of registered vessels* UBPP will decrease, which shows a negative (-) UPV", i.e., as abbreviated: BOPD(+)→ (-) UBPP.
"If the *average staying time of vessels* PVZP increases, then *the number of vessel checkouts a day* BOPD decreases, which shows a negative (-) UPV", i.e., as abbreviated**:** PVZP(+)→(-) BOPD.

(-) FBL1: The variables UBPP and BOPD create the so called negative (-) retroactive circle, or self-governing (-) KPD1", i.e., as abbreviated**:** UBPP(+) → (+)BOPD(+)→(-) UBPP.
"If the *number of vessel checkouts a day* BOPD increases, *the total value of the issued invoices* UVIR will also increase**,** which shows a positive **(+)** cause-effect connection UPV", i.e., as abbreviated: BOPD(+)→(+)UVIR.
"If the *average time of stay of vessels* PVZP increases, *the number of vessel checkouts a day* BOPD will be decreased, which shows a negative (-) UPV, i.e., as abbreviated: PVZP(+) →(-)BOPD.

"If the *average realised revenue per vessel per day* POPPD increases, *the value of the issued invoices a day* VIRD will also increase, which shows a positive (+) UPV, i.e., as abbreviated: POPPD(+)→(+)VIRD.

"If the *value of the issued invoices a day* VIRD increases, *the total value of the issued invoices* UVIR will also increase, which shows a positive (+) cause-effect connection UPV", i.e., as abbreviated**:** VIRD(+)→(+)UVIR.

"If the *total value of the issued invoices* UVIR increases, *the value of the collected debts a day* VNPD will also increase, which shows a positive (+) cause-effect connection UPV: UVIR(+) → (+)VNPD.

"If the *average time of collecting debts* PVNP increases, *the value of collected debts a day* VNPD will decrease, which shows a negative (-) cause - effect connection UPV". PVNP(+)→ (-) VNPD..

"If the *value of collected debts a day* VNPD increases, the *total value of issued invoices* UVIR will decrease, which shows the negative (-) UPV." VNPD(+)→(-)UVIR.

The remaining FBL are shown in short form as follows:

(-) FBL2: The variables VNPD and UVIR create the so called negative (-) retroactive circle, or self-governing (-) FBL2", i.e., as abbreviated: UVIR(+)→VNPD(+)→(-)UVIR.

(-) FBL3: The variables SUSZR and VISZRD create the so called negative (-) retroactive circle, or self-governing (-) FBL3",, SUSZRD(+)→VISZRD(+)→(-)SUSZRD.

(-) FBL4: The variables **VUD and VIOPD** create the so called negative (-) retroactive circle, or self - governing **FBL4**", VUD(+) → VIOPD(+)→(-)VUD.

The value of investment into new capacities – VINK will be determined:

VINK.KL=DELAY3(PULSE(500000,1,380,1000),180)+DELAY3 (PULSE (2000000, 1, 400, 1000),180)

Remark: The first item of the equation VINK.KL (500,000 EUR) denotes the total investment of the marina during the construction period of 180 days (its own financial means and bank loan as the outer finances); the other item of the equation denotes the possible investment in total of 2 million US$ of the foreign partner investors, and it will not have a negative effect (increase of costs) to financial state of the giro account, but the new investor will ensure the return on investment by an agreed share in the profit.

The investment effect will reflect for the first time in the realisation of the increased revenues in the following season.

Positive effects of the investment will reflect in the variable KPNI coefficient of the increase of new investments:

KPNI.K=TABHL(KPNIT,VINK.KL,500,^
2500,500)

KPNIT=1,1.2,1.5,1.8,1.9

The variable KPNI denotes an increase of revenues in the future period (after completing the investment and the beginning of work of the completed new capacities). The symbol KPNIT denotes the tabular amplitudes of a relative factor of increase of new investments to the growth of total revenues, costs, average costs per vessel and the generator of vessel arriving.

The state of the total assets in the giro account – SUSZR, will be determined:

SUSZR.K=SUSZR.J+DT(VUSZRD.JK-^
VISZRD.JK),

Remark: If the state of the total assets in the giro account is higher than zero, then the marina is solvent, and if it is zero or less than zero, then it is financially insolvent and in order to be capable to pay its liabilities it has to ensure cash assets on the basis of loans (mid-term or short term loans).

SYSTEM DYNAMICS STRUCTURAL FLOW DIAGRAM OF THE NTBS

In accordance to the completed mental and verbal simulation model of investing into sports and other objects in the NTBS business system, it is possible to determine the system dynamics simulation flow diagram of NTBS.

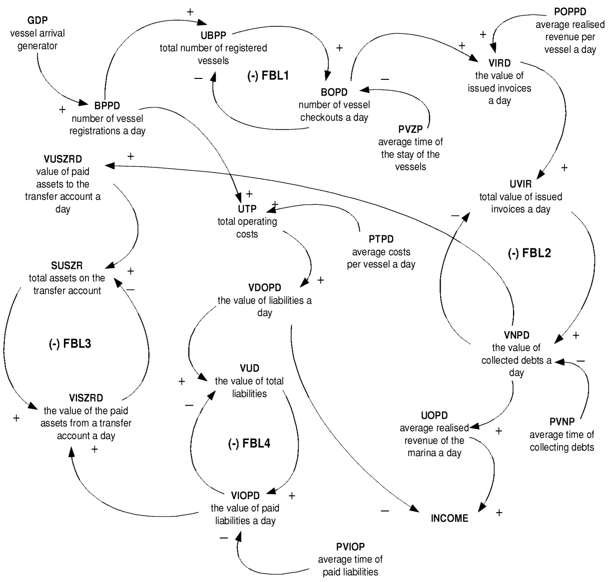

Figure 1: System Dynamics structural model of NTBS

THE RESULTS OF SIMULATIONS OF 0/1-SCENARIO OF NTBS RELATING TO INVESTING INTO NEW SPORTS OBJECTS

Graphic results of the simulation following variables:

SUSZR= state of total assets of the cash flow;
UVIR= total value of issued invoices;
UBPP= total number of registered vessels
UOPD= average realised revenue of the marina per day;
UTP – Total operating costs
INCOME – Income of NTBS (euro /year)
VUD – The value of total liabilities
VINK – The value of investments into new capacities
BOPD – Number of vessel checkouts a day
VIRD – The value of issued invoices a day
VUSZRD – The value of paid assets to the cash flow day

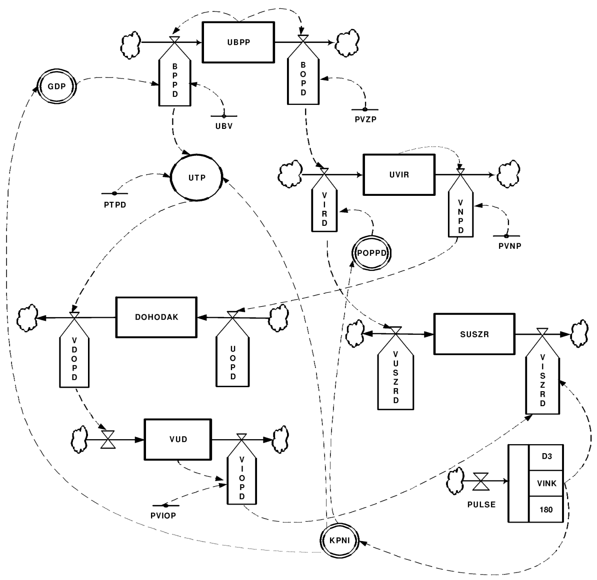

Figure 2: SD Structural flow diagram of the NTBS

The following figures show the state of the variable depending on the input variable GDB (generator of vessel arrival). For scenario 0 input variable is: GDP.K=STEP(100,100), a scenario 1 input variable is GDP.K=STEP (100,100)*PULSE(8,1,120,2)*(2-NOISE()).

Comments

Analysing the obtained graphic results of the simulation of 0 scenarios it is possible to notice that performance dynamics of variables is in accordance with economic regularity of the

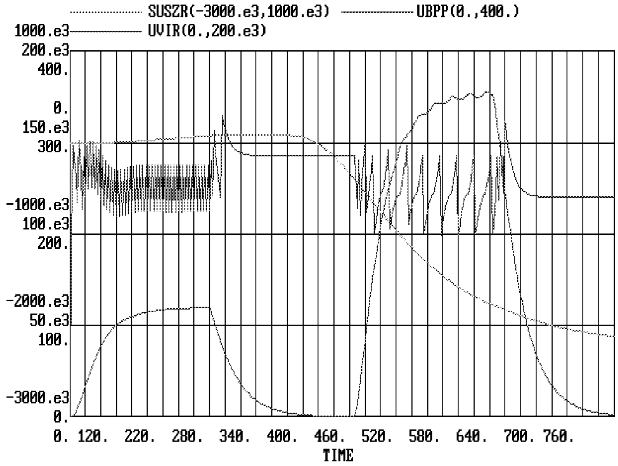

Figure 3: Graphic presentation of the simulation of 0 scenario – variables SUSZR, UVIR and UBPP

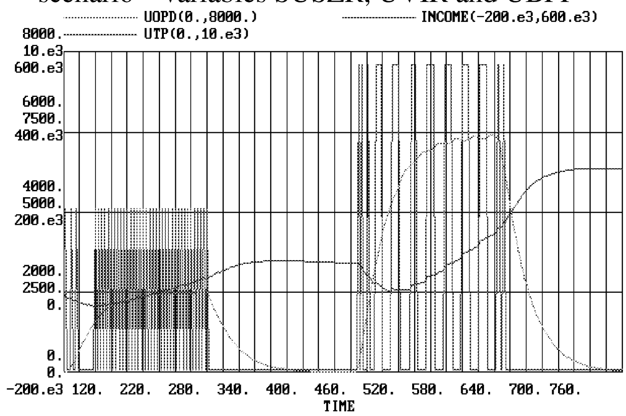

Figure 4: Graphic presentation of the of 0 scenario - variables UOPD, INCOME and UTP

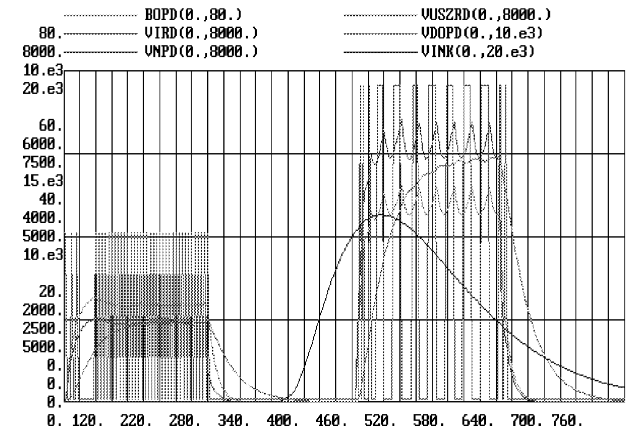

Figure 5: Graphic presentation of the of 0 scenario – variables BOPD, VIRD, VPD, VUSZRD, VDOPD and VINK

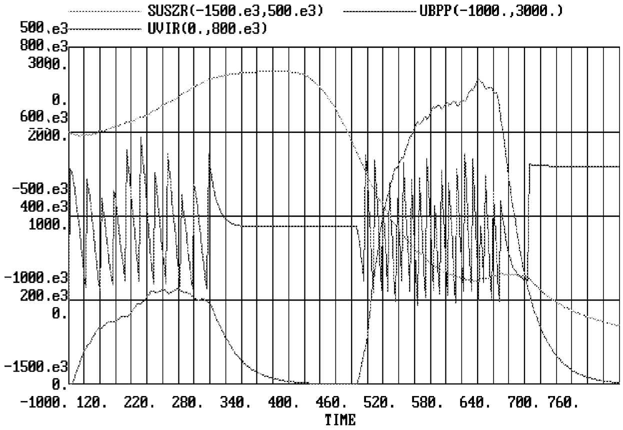

Figure 6: Graphic presentation of the simulation of 1 scenario – variables SUSZR, UVIR and UBPP

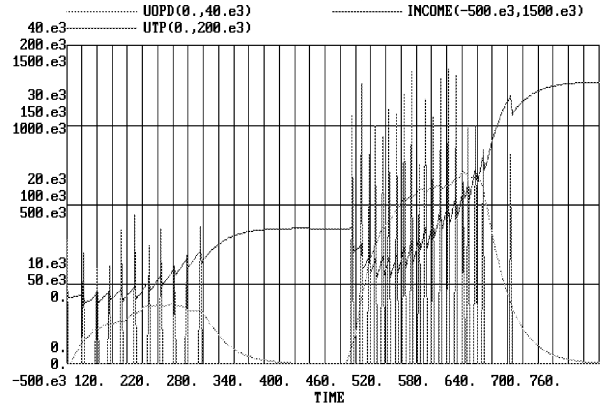

Figure 7: Graphic presentation of the of 1 scenario - variables UOPD, INCOME and UTP

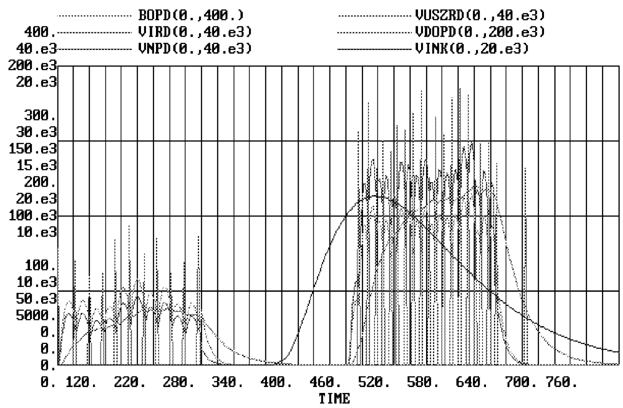

Figure 8: Graphic presentation of the of 1 scenario – variables BOPD, VIRD, VNPD, VUSZRD, VDOPD and VINK

NTBS as a unit within its surroundings.
The total number of registered vessels – UBPP, will in the first tourist season realise a maximum of 285 vessels, while in the following season, due to the gradual finishing of the investments into new capacities, or sport and other objects, the interest of the nautical tourists will increase, which will result in the increase of the total number of vessels, and thus the highest number of registered vessels, in total of 292 a day TIME=530. The characteristic of the number of vessels is stochastic.

The total realised income per day – UOPD, in the first tourist season will reach it's maximum of about 641 EUR per day, while in the following tourist season, due to greater offer of sports facilities, the income of 6,749 EUR a day (TIME=555 day) will be realised.

In the first tourist season, or the period of TIME=120 day to TIME=304 day, the income of the marina has a negative value (loss) with the greatest loss of 0.33 EUR a day TIME= 240, after which it becomes positive on the day TIME=304 to the new tourist season on the day TIME=486, and reaches its highest amount of 78,860 EUR a day on the day TIME=392. In the period of the following tourist season TIME=486, the income is negative, and it has the highest loss in the amount of -2,000 EUR a day on the day TIME=530. This loss will gradually decrease, and it will become positive again on the day TIME=542, and by the end of the second tourist season will remain positive, reaching its maximum value of 309,500 EUR a day on the day TIME=790.

In the first tourist season the total operating costs UTP are in their highest amount of 5,100 EUR a day on the day TIME=184, and have stochastic character. In the first off-season period UTP from the day TIME=302to the day TIME=485 they have their constant off-season value of 100 EUR a day, and cover all operating costs of the marina out of the season. In the second tourist season which starts on the day TIME=485, the costs grow to their maximum of 4,279 EUR on the day TIME= 492. In the second off-season period the costs have again the value of 100 EUR a day.

The state of the total assets in the giro SUSZR in the first part of the tourist season to the day TIME=195 have a negative value, with the maximum shortage of cash money of –2,902 EUR on the day TIME=156. Thus, from the day TIME=170 SUSZR becomes positive, realising the highest amount of assets of 86,050 EUR on the day TIME=364 and retaining that value for several days. Before the beginning of the new, second season on the day TIME=417 SUSSZR again becomes negative, because of new investments, and reaches its maximum of 2,118E3 EUR on the day TIME=519, after which it becomes positive again on the day TIME=631 the end of the simulation period.

The work was given second scenario in which we increase the number of vessels in the marina. The results of simulations are shown in pictures 6, 7, and 8. With the increase of vessels in a marine, the value of observed variables will increase.
The total realised income a day – UOPD, in the first tourist season will reach its maximum of about 758 EUR a day, and by the end of the second tourist season will remain positive, reaching its maximum value of 22,520 EUR.

The income of the marina has a negative value in beginning of scenario 1 (from TIME=120 to TIME=226), after that has positive values to end of scenario 1 and reaches its highest amount of 1,271E3 EUR a day on the day TIME=810.

In the first and second tourist season the total operating costs UTP has stochastic character, and first tourist season the total operating costs UTP are in their highest amount of 86,580 EUR a day. The second tourist season's highest amount of 183,600 EUR a day.

The state of the total assets in the giro SUSZR in the first part of the tourist season to the day TIME=158 have a negative value, with the maximum shortage of cash money of –20,790 EUR a day. After that it has positive value to end of the first tourist season. In the second tourist season SUSZR has a negative value.

On the basis of the comments of the results of NTBS, and in view of the two observed tourist seasons and the considerable investment with the aim of improving business as a whole, it may be concluded that the observed NTBS business system for such a scenario 0 and scenario 1 of the observed development period is stable and it gives positive financial results (revenues, income, solvency etc.) and total positive results in the observed period.

CONCLUSIONS

On the basis of the system dynamics research of the performance of the complex business system NTBS, with the aid of a fast digital computer on which the performance simulation was done, it is possible to bring forward a number of relevant conclusions:

1. A direct application of system dynamics simulation complex models in the field of scientific research of performance of nonlinear management systems has full rationalization, because it ensures to the model constructor an extremely suitable software medium which may be determined as intelligent models of the second generation, if the first generation refers to present expert systems.
2. System dynamics and its efficiency of intelligent modelling of a business system may be considered as a logic order of development of intelligent systems in the field of applying research of dynamics of cybernetic business systems.
3. System dynamics uses special methodology and special software packages, the most outstanding being: DYNAMO; Powersim, Stella, Vensim, and iThink.
4. System dynamics is especially convenient for the study of performance dynamics of business systems in which a great number of non-linear retroactive circles operate, or for systems where at operating the system the use of manager's intuition alone fails.
5. A special importance and quality of applying system dynamics in education, training, designing and exploitation of complex business management systems may be considered in acquiring new knowledge which classic management methods cannot offer.

On the basis of the above presentation, the authors of this paper recommend the implementation of system dynamics methodology tool into all fields of human activities with the aim of understanding various complex systems, in which the experiment cannot be performed in real life without jeopardizing their existence, growth and development.

The possible scientific contribution of this paper is primarily in authorised determining of general multiple simulation models which allow for acquiring new knowledge about dynamic performance of real nautical and tourist business systems, but also sports organisation systems. Also, in order to follow successfully the development of modern sports industry, the students of kinesiology need knowledge and skills in various areas, especially economy, management and marketing. By using the proposed tools and system dynamics simulation methodology, the students will acquire knew knowledge about performance dynamics of complex organisation systems in the field of tourism, sports and recreation.

Instead of conclusion, it should be useful to quote a well-known Chinese proverb:

"When I hear, I forget.
When I see, I remember.

When I do, I understand".

But it is also useful to modify it in the marine system engineering way:

"WHEN I HEAR A MENTAL-VERBAL MODEL OF A DYNAMIC PROCESS, I FORGET".
"WHEN I SEE A STRUCTURAL MODEL AND REALITY OF A DYNAMIC PROCESS, I REMEMBER".

"WHEN I DO A MATHEMATICAL OR COMPUTER SIMULATION MODEL OF A DYNAMIC PROCESS, I UNDERSTAND".
"WHEN I DO A SYSTEM DYNAMICS MODEL OF A. DYNAMICS PROCESS, I LEARN".

" WHEN I DO SIMULATIONS OR TRAINING BY SYSTEM DYNAMICS MODEL OF A DYNAMIC PROCESS, I WILL DO REFRESHMENT WITH THE MY ACQUIRED THEORETICAL AND PRACTICAL KNOWLEDGE OF A DYNAMIC PROCESS."

REFERENCES

Coyle, G. R. 1996. "System Dynamics Modelling", Chapman & Hall, London.

Čerić, V., Varga, M. and Birolla, Hugo, 1998. "Poslovno računarstvo", Znak, Zagreb.

Dulčić, A. 2003. „Nautički turizam i upravljanjem lukom nautičkog turizma, Sveučilište u Splitu", Split.

Dulčić, A. 2001. „Upravljanjem razvojem Turizma", Mate, Zagreb.

Munitić, A. 1989. „ Kompjuterska simulacija uz pomoć sistemske dinamike, Brodosplit, Split.

Pidd, M. 1997.: "Computer Simulation in Management Science", Wiley, New York.

Čerić, V. 1993.: *Simulacijsko modeliranje*, Školska knjiga, Zagreb.

Waren, K. 2002. "Competitive Strategy Dynamics", John Wiley & Sons,Chichester, Englaand.

Pidd, M. 1997. "Computer Simulation in Management Science", Wiley, New York.

Richardson, G.P. 1986 „Problems with causal – loop diagrams", Sistem Dynnamics Review 2:158-170.

Garcia, J.M. 2006 „ Theory and practical exercises of system dynamics", First edition in English March.

Barlas, Y. 1996. „Formal aspects of model validity and validation in system dynamics, System Dynamics Reviea, Vol, 12, No.3, 183-210.

Coyle, R.G. 1977. „Management system dynamics", John Wiley, New York.

Randers, J. 1980. „Elements of the system dynamics method", MA Productivity Press,

Sterman, J. D. 1985. Deterministic chaos in an experimental economic system", Jurnal of Economic Behavior and Organization 12.

Forrester J.W., 1984. „ Urban Dynamics", MIT, Cambridge, Massachusetts, and London, England, Seventh printing, Copyright 1969 by MIT

Forrester J.W. 1980." Principles of Systems", MIT Press Cambridge, Massachusetts, and London, England, Second Preliminary Edition, Ninth Printing, Copyright 1968 by Jay W. Forrester

Lyneis, M., James 1982. "Corporate Planning and Policy Design: A System Dynamics Approach", MIT Press Cambridge, Massachusetts.

Waren, K. 2002. "Competitive Strategy Dynamics", John Wiley & Sons, Chichester, England.

BIOGRAPHY

ANTE MUNITIĆ received a double BS in 1. Electro-Energy Engineering and 2. Electronic Engineering, and a MS in Electronic-Operating Research at the University of Split, Croatia, and a Ph.D. degree in Organization Science (System Dynamics) at the Belgrade University, Yugoslavia. All degrees were earned while actively engaged in teaching at the university. He is now Full Professor Doctor of the Computer & Informatics Science and is a Maritime-Faculty University Professor of the following courses: 1. Computer science, 2. Marine Systems and Processes Management Modelling (System Dynamics) and 3. Marine Integral Information Systems. His research interests are 1. Researching System Dynamics Methodology, 2. Relative System Dynamics (optimization), 3. System Dynamics Analogizes, and 4. Chaotic System Dynamics. He is a member of the Society for Computer Simulation and the System Dynamics Society.

THE MAINTENANCE MANAGEMENT IN THE HIGHWAY CONTEXT: A SYSTEM DYNAMICS APPROACH

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KEYWORDS
System Dynamics, Decision Cockpit, Maintenance Management, Simulation.

ABSTRACT

Being a complex process and a predominant cost component, the maintenance management represents, for the highway context, one of the most critical aspects to take into account for a company concessionaire of the highway service. This is even truer for difficult environments, such as the mountain one, where the particular geographical features requires stricter and more expensive maintenance plans.
The paper presents a real case study on the management of the maintenance operations for the A32 highway, which links the city of Turin with France, passing through the mountain range of Alps in the Italian territory.
Utilizing a system dynamics (SD) approach enabled by the Powersim software, a model of the particular maintenance system has been created and implemented. Moreover, an optimization of the number of working yards, of the costs related to the total expenses of maintenance with particular regards to the penalties due to a failed respect of the imposed constraints, has been put into place.
In order to efficiently manage in real time the complex implemented model, an opportune decision cockpit has been developed and connected to a vast database filled with continuously updated data.

INTRODUCTION

The A32 highway tract "Turin – Bardonecchia – Frejus" represents a very important crossroads of traffics as it connects Italy with France, putting into communication Turin and Lion, which are two very important cities both from the industrial and commercial standpoint. Besides, the A32 highway is located along the crucial Corridor V, which links Lisbon and Kiev, and finally it is quite important also from the touristic point of view, allowing to reach famous mountain places such as Sestrière, Oulx or Bardonecchia.
Due to its geographic location, the A32 presents a very particular type of outline, with numerous viaducts and tunnels, which require perfectly efficient plants and consequently a very high attention to grant safety both for users and operators.
For all these reasons it has been decided to consider the 73 km of this highway as a valid case study for the maintenance issue. In particular the main goal of this paper is to properly model the functioning of the maintenance management system of the A32 Italian highway and to provide an efficient decision support system that can be highly integrated with the major type of database and Enterprise Resource Managament (ERP) systems.
The model has been constructed using the Powersim software which is based on the system dynamics methodology that proved to be very efficient in modelling the internal structure of a system and to easily connect the model with databases and ERP systems.
The paper is organized as follows: after an introduction regarding the reference context, the description of the SD simulation model is presented, with a particular focus on two model parts: one related to the FMECA (Failure Mode, Effects, and Criticality Analysis) analysis and another one to the traffic impact. A chapter is then dedicated to the optimization phases and the relative genetic algorithm which is at the basis of the Powersim optimizer. The following chapter regards the decision support system (DSS) implemented with Powersim, which allows to better manage the simulation model and to facilitate decision makers in taking the best decisions regarding the maintenance management. Finally, some results and conclusions are presented.

DESCRIPTION OF THE MODEL

The simulation model here proposed is able to efficiently describe the maintenance management system related to the Italian A32 highway tract, and above all it provides a valid support system for taking decisions regarding its most appropriate maintenance management. In particular, the combination of a double steps optimization and an efficient DSS allows to formulate an optimal maintenance policy, able to reduce the number and length of the working yards and, as a direct consequence, the total costs. At the same

time it is possible to maximize the level of service to the final users, taking into account all the impacts in terms of traffic and the safety of people that daily utilize or work on a particular highway tract.
The model considers the following set of dimensions:

- segments: the highway tract has been divided in 15 tracts of equal length (5 kilometers each). The kilometric position of the items is related to them;
- ways of direction: they are in number of two and indicate the direction of the carriageway (towards Turin or towards Frejus);
- item families: the model operates on a series of plant typology that are subject to failures inside a precise period. More precisely there have been identified 13 typologies of item families (Transmission Ring, Ice Panel, Radio, Variable Message Panel, Smoke Detectors, SOS column, Phones, TVCC-TV Closed Circuit, UCS-Traffic Light Systems, Video Wall, Broad Band, Rain Panel and UPS) that are subject to failures inside a precise period: for a matter of simplicity it has been assumed that they coincide with the failure modes (for instance a breakdown on the Variable Message Panel is uniquely identified both if there is a failure regarding pixels or if the feeder has been broken: what matters is that the failure refers to the Variable Message Panel).

The simulator determines the life of each item family, located in a particular segment and direction. When an item is subject to a failure, it is necessary to repair it through a corrective maintenance. Moreover it is also expected a preventive maintenance, which occurs at pre-determined time intervals in order to prevent the failure of the component. For both kinds of maintenance it is required the presence of working yards, which have an impact on the vehicular traffic fluidity, limiting the potentialities of the interested highway tract (segment).

Figure 1 shows the logic at the basis of the simulation model, which is composed by three main modules: strategic, tactic and operative.

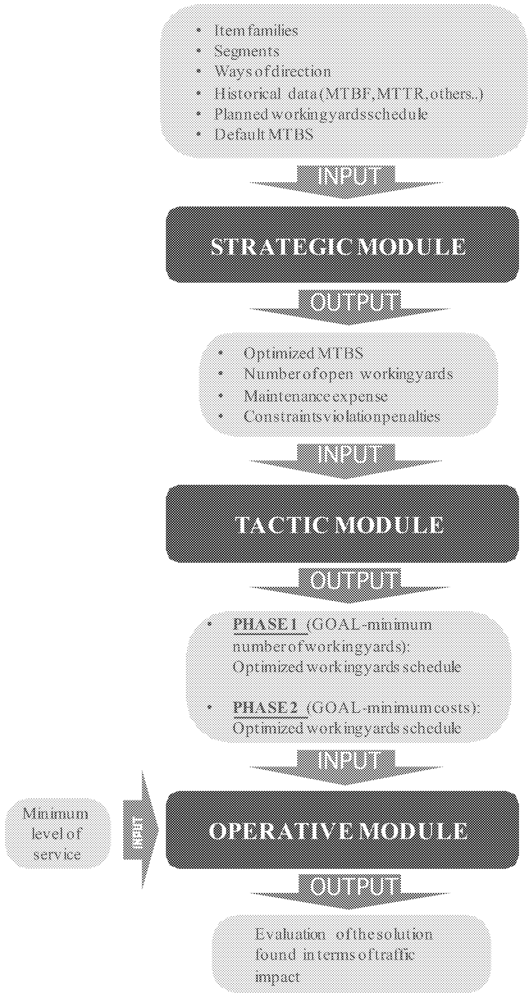

Figure 1: The logic at the basis of the simulation model (strategic, tactic and operative modules)

As shown in Figure 1, the strategic module takes in input:

- the model dimensions (item families, highway segments, ways of direction);
- the historical data related to the maintenance interventions: the MTBF (Mean Time Between Service, which represents the time interval between two preventive maintenance interventions for the same item family), the MTTR (Mean Time To Repair, which corresponds to the average time before the reparation, etc.) and dates of interventions beginning and end;
- a planned working yards schedule (provided in terms of time, segments, directions, type of interventions, number and length of closed lanes);
- the default MTBS which is equal to the average MTBF calculated on the basis of the most suitable distribution probability derived from a set of historical data.

More precisely the historical data related to MTBF and MTTR, before being used by the simulator, are manipulated in order to provide the most suitable probability distributions for each particular item (most of them belong to the weibull, negative exponential, triangular and uniform distributions).
The strategic simulation module is able to determine the life of each item family, located in a particular segment and direction, starting from a series of historical data that are automatically inputted in the model.

This first module gives in output an optimized MTBS. Additionally, it provides the number of open working yards, the total maintenance expense and the penalties due to the constraints breach. All these outputs represent a series of inputs for the tactic module, which is composed by two different phases. The first one has the goal of minimizing the number of working yards, while the objective of the second phase is to minimize the total maintenance costs. So the two phases provide in output an optimized working yards schedule, firstly focusing on the optimal number of working yards and subsequently on the minimum possible cost.
The final module (which is the operative one) represents the detail simulation: it receives the optimized working yards schedule - in terms of number of working yards and total costs - and, taking into consideration a minimum threshold of the highway users' service level, evaluates the solution found by the tactic module in terms of its impact on the highway traffic. If, under this point of view, the solution is not acceptable, a new working yard schedule has to be rethought, till an acceptable solution is found.
Furthermore the model provides other interesting outputs as the tract dangerness and the acustic and gassy emissions, which are useful parameters for the choice of the best maintenance plan determined with the Analytic Hierarchy Process (AHP) technique developed by Thomas L. Saaty. To this scope it has been developed an *ad hoc* interface which faithfully recreates the network and logics of the multicriteria decision techniques.

It is worth specifying that in order to generate the random numbers useful for the simulations, the simulator utilizes the "Monte Carlo" statistical method, being this methodology the most appropriate in the study of situations in which there is a high uncertainty degree and the happening of events can be determined only through a probability coefficient. More specifically the Monte Carlo method generates random numbers (usually between 0 and 1) which are used as primer seeds for the simulator.

Hereafter, in order to provide an insight of the system dynamics model, two relevant sub-models will be shown: one related to the FMECA analysis and the other one regarding the traffic network system.
Figure 2 shows the first of the two. The logic at the basis of the FMECA analysis sub-model is the following: starting from the initial values of MTBF and MTBS (the first one is calculated according to the best fitting probability distribution, while the second one is a function of the default MTBS multiplied by a proper coefficient, which is an output of the strategic module), the number of hours to the next failure or service decreases linearly because of the higher increasing of the exiting flows "on duty – service" and "on duty – failure", meaning that while time is passing, it is approaching the possibility that the items fail or is interested by preventive maintenance.
Unavoidably one of the two values ("hours to the nest failure" or "hours to the next service") will reach the value of zero (the time evolution of the item status is visible in Figure 6 with the red line for failures and the green line for service), causing the switching to true of the logical flow "in failure", which automatically turns to false the "on duty" level.
At this moment the maintenance intervention starts (with possible delay) and the component stays under repairing or under service until the MTTR (or MTTS) time has been elapsed.
Once the intervention has finished, the component exits from the failure/service state and then the "on duty" level returns to true, making the hours to next failure and service return to the MTBF and MTBS level, drawing a sawtooth profile graphic.

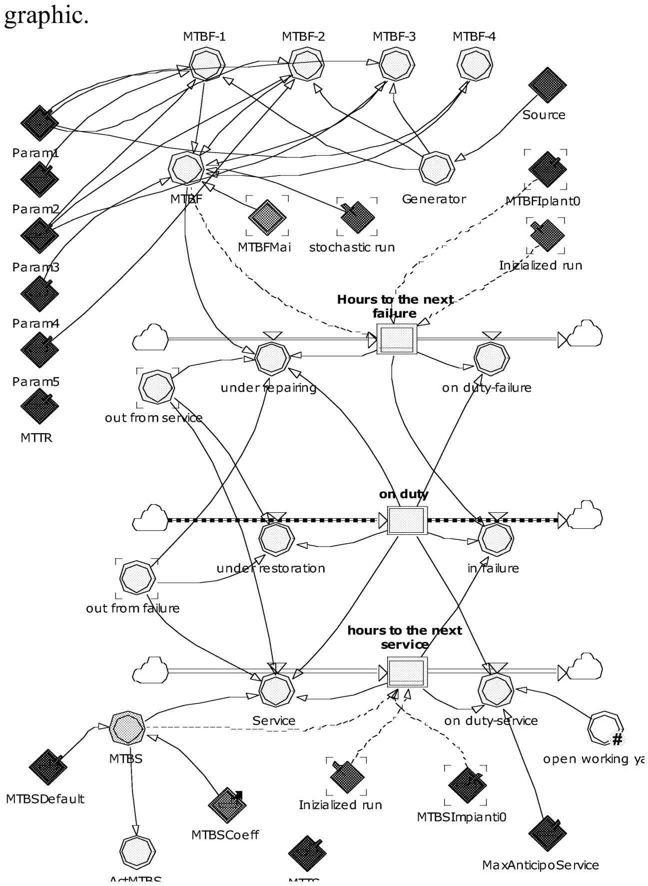

Figure 2 : the system dynamics FMECA analysis module

The FMECA analysis module follows the classical rules of the FMEA/FMECA methodology, where the reliability R(t) is function of the failure rate F(t), as showed by (1).

$$F(t) = \int_0^t f(t)dt \qquad (1)$$

where $R(t) = 1 - F(t)$

with $0 < t < \infty$, $F(0) = 0$ and $F(\infty) = 1$.

Figure 3 instead shows the SD traffic network module, where the main flow is characterized by the balancing of ingoing and outgoing vehicles inside a specific segment; the parameters that mainly affect the traffic flow are the vehicle speed and the vehicle density. The first one is set, in condition of flowing traffic, to the maximum value of 130 km/h (kilometres per hour), according with the Italian Route Code. However, the vehicle speed is heavily affected by the traffic condition: due to factors like the presence of working yards, seasonality, weather conditions (snow is frequent on the A32 motorway), the traffic density plays an important role. In fact, as a very simple example, if there is a queue of cars proceeding at a certain speed, the cars which follow have to keep the speed of the queue and so it is not possible to maintain the regular one.

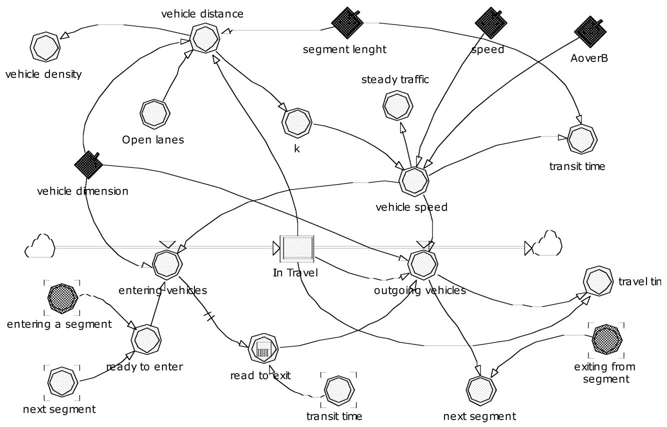

Figure 3: The system dynamics traffic module

As shown in Figure 4, the vehicle speed can be graphically represented with a decreasing straight line (A/B) where A is the maximum reachable speed (130 km/h) and B is the threshold value of density for traffic jam. If the B value is low, the traffic is fluid and so an higher speed is sustainable; vice versa, if B is high, the traffic is intense and so the speed becomes lower.
At last, dividing the section length by the determined speed, it is calculated the transit time for a segment, which is different from the "travel time" auxiliary variable: the travel time is something similar to the Little's Law "Cycle Time", while the "transit time" is something instantaneous that assumes a different value at each time interval.

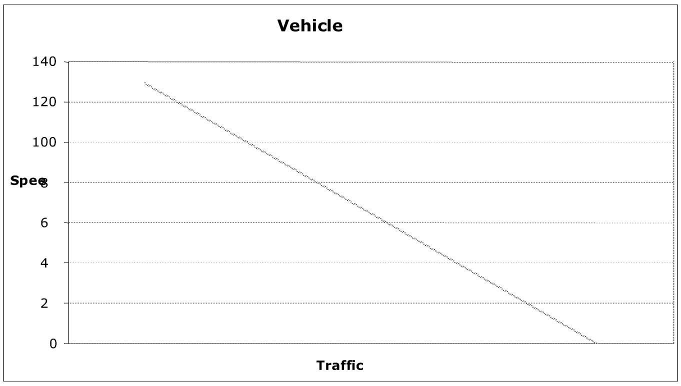

Figure 4: Vehicle speed trend graph

In literature the Little's law states that the Work in Progress (WIP) is the product of the Cycle Time (CT) by the throughput (TH):

$$WIP = CT * TH \quad (2)$$

In the case here presented the formula is used in an inverse way: the WIP is known, because it is calculated inside the level "in travel", taking into account all the ingoing vehicle flow coming from the previous sections and entering the current section, while the Throughput is calculated inside the flow rate "outgoing vehicles", which considers the vehicles moving to the following section.

Consequently the travel time is calculated as the ratio between the Vehicles on Travel and the Outgoing Vehicles.

As far as regards the model validation, the strategic and tactic modules have been validated through proper experimental campaigns comparing the obtained results with theoretical reference models.
The detail module, related to the traffic management, has been tested both in a static regime (traffic) and a dynamic one (flow variation, working yards opening).
Moreover the MTBF and MTBS diagrams have been verified during proper workshop with the concessionaire company staff.

THE OPTIMIZATION PHASES

The optimizations steps on working yards and on costs have been carrying out through the optimizer integrated in the Powersim software. The genetic algorithm search procedure, which is at the basis of this optimizer, is conceptually based on the Darwin's principles of the survival of the fittest. The optimization is reached through biological evolution emulation, borrowing from this natural process terms such as population, mutation, reproduction, genes and chromosomes in order to describe the genetic algorithm method.
At the first step the algorithm generates a population consisting of a user-defined number of randomly generated solutions. These solutions are initially compared, for instance considering one chromosome, retaining the ones that present the best fitting of the objective function for the recombination process and discarding the ones that provide no improvement to the objective function.
During the recombination process, then, the value of a couple of chromosomes is exchanged on each pair, in order to provide another two sets of chromosomes (crossover process). In this case the two original solutions are considered to be parents while the two set of chromosomes newly generated are considered to be children or, named technically, offspring. These offspring are then assessed for fitness and manipulated in the same way as their parents were; the process continues for a fixed number of iterations until a desired tolerance within the desired outcome is achieved.
Inside the Powersim optimization tool, some parameters and decisional variables need to be defined. In the case here proposed for the A32 highway, all these parameters and variables needed to be provided for each of the three optimization modules contained in the simulator, varying them on the basis of the optimization requested (strategic module, the tactic module-phase 1 and tactic module-phase 2).
In the strategic module optimization phase 20 replications have been carried out for each launch with the goal of obtaining the optimal level of preventive maintenance, with the constraint of a minimum percentage of 90% for the global reliability. The elaboration time of the strategic module, considering a generation of 300 solutions and 100 seeds, has been about 1 hour.
Table 1 shows all the variables (and relative values) of the strategic module optimization, in terms of assumptions, decisions, objectives and effects.

Table 1: Strategic module optimization variables

	Variable	Value
Assumption	Source	from 0,001 to 1 (Uniform)
Decisions	MTBS Coeff.	from -4 to 4
Objective 1	Availability	> 90%
Objective 2	Maintenance Expense	Minimum

Once setting the optimal level of preventive maintenance (optimized MTBS) the model allows two other optimization steps:

1. on the working yards starting dates, with the goal of reducing the number of yards (phase 1 of the tactic module);
2. on the intervention starting times, with the objective of reducing, once fixed the optimal number of working yards, the costs related to the maintenance and to eventual fines related to the overcoming of the maximum times of out of service for a particular item family on a specific segment (phase 2 of the tactic module).

The tactic optimization procedures require an average machine time of 5 minutes each.
Table 2 and Table 3 refer to the variables relative to the first and second phase of the tactic module optimization respectively. As already specified, the objective of the first phase is to minimize the number of working yards, while the second phase goal is to minimize the total maintenance costs.

Table 2: Parameters and decisional variables for the first phase of the tactic module

	Variable	Value
Assumptions 1	Interv. Delay	0 (fixed)
Assumptions 2	Source	0,5 (fixed)
Decision	Working Yard Delay	from -9 to +9 days
Objective	Open Working Yards	Minimum

Table 3: Parameters and decisional variables for the second phase of the tactic module

	Variable	Value
Assumptions 1	Source	0,5 (fixed)
Decisions	Intervention Delay	From 0 to 47 hour
Objective 1	Open Working Yards	Minimum
Objective 2	Costs	Minimum

THE DECISION COCKPIT

In order to provide an easy way to interact with the simulator with the final goal of carrying out what-if analysis and taking the most proper decisions under different operative contexts, a Decision Support System (DSS) has been created with the Powersim software. Figure 5 shows the main interface of the DSS, which is perfectly integrated with the concessionaire databases.

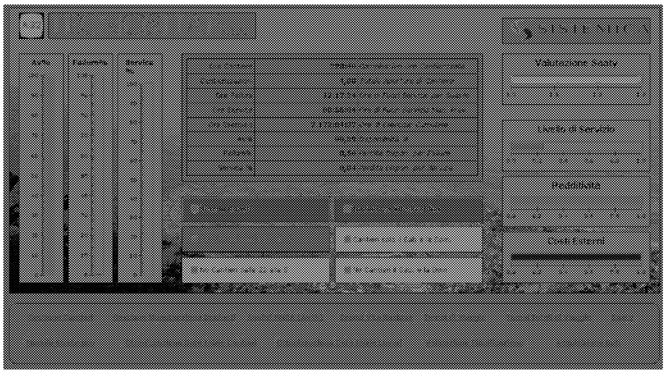

Figure 5: The main interface of the simulator

Operatively the procedural steps to carrying out a complete simulation launch are the following: after having captured all the necessary input data from the databases, the strategic module is launched in order to calibrate the correct level of preventive maintenance.
Moreover the main interface provides a global view of the fundamental reference indicators (Figure 1).
It can be decided to perform a "flexible" simulation, setting different constraints and parameters like for instance night working yards or working yards allowed only in the weekend. It is also possible to look at important key performance indicators such as the items availability, the loss for failures, the loss for service, the user service level, the Saaty evaluation, the profitability and the external costs (which take into account the accident level in a tract, the segment congestion level and environmental issues in terms of gassy and acoustic emissions).
From the main interface of the decision support system it is possible to access, through a series of links, to other model interfaces.
The "road construction sites management" interface allows to give a glance to the situation of a certain working yard in a determined segment along the simulation time interval. Besides it allows to manually modify the working yards length or their beginning dates.
The "Plant maintenance management" interface provides instead the reliability analysis for a particular plant family.
The "FMECA Analysis" interface has the objective of representing the global current situation about the reliability for each segment and way of direction.
The "Residual life" interface shows to the user the life trend of a particular plant, on a particular tract segment and in a specific direction. The graph in Figure 6 highlights the MTBF trend (in red color) and of MTBS (in green color), which linearly decrease until one of the two reaches the value of 0: in that moment an item block is activated (for a failure or service depending on who arrives first to 0, the red line or the green one).

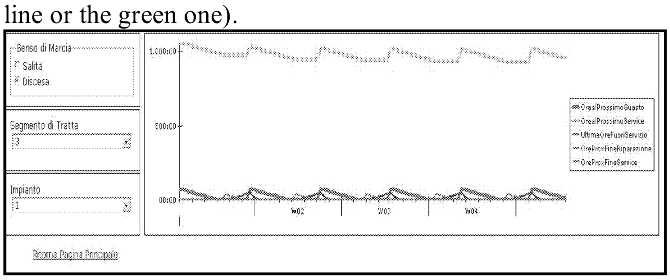

Figure 6: The “Residual life” interface

Once the plant is still, it can be restarted immediately or in a following moment: in this latter case the blue line, which represents the out of service hours waiting for the repair, deviates from 0. It will reach the 0 again when the restoration intervention is started. In Figure 6 it is also possible to note the MTTR trend (brown color) and the MTTS one (pink color), which assume values non null during the fault or the service till they exhaust with the end of the intervention.

The “Saaty” interface shows the multi-criteria hierarchical structure built according to the AHP theory by T. Saaty, where the root is the objective function, represented by the best maintenance plan, and the following levels are represented by the various criteria and sub-criteria.

The representation faithfully reproduces the network created through the “Super Decisions ®” software and the calculation methodologies of the super matrices weights, inserting the formulas of the decisional multi criteria theory in the simulator code.

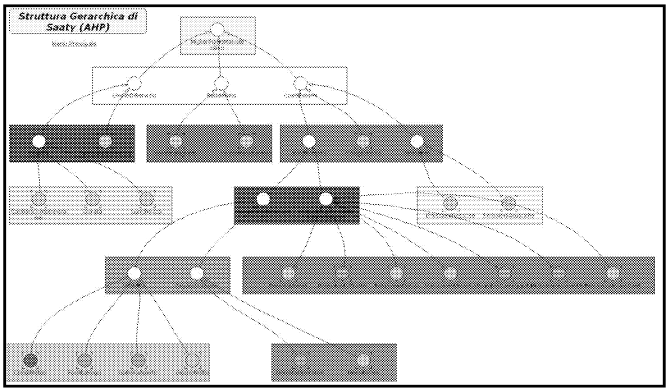

Figure 7: The “Saaty” interface

The “Working yards starting date optimization” interface shows a table containing parameters related to the optimization of the working yards starting dates rather than the preventive maintenance level. The number of open working yards will be reduced in respect to the first optimization results.

The optimization goal is to reduce the number of working yards intervening on their starting dates, so allowing eventual working unifications, avoiding lanes closings and openings which can significantly impact on the traffic.

RESULTS AND CONCLUSIONS

It can be said that the simulation model and the relative Decision Support System here described showed to give very interesting and effective results. For instance, considering as test case the Variable Message Panel item on the section number 3 in the Turin direction, after the launch of the first step of the tactic module, we obtained a decrease of the 17% on the number of open working yards (from 17 to 14); while the second optimization phase, keeping the number of working yards “frozen” to 14, made the total costs decreasing of 4.1 %, passing from the initial 17460 € to the optimized value of 17106 €. The results are summarized in table 4.

Table 4: Results obtained with the tactic module optimization for a specific case

	Strategic Phase	**Tactic Phase 1**	**Tactic Phase 2**
Working Yards	17	14	14
Tot. Expense	16392,00	17460,00	17106,00

Finally, the simulation model here presented - thanks also to its fully integration with the company databases for the recovery of the necessary inputs in terms of historical and planning data – proved to be able to provide precious information to the maintainers for taking the best decisions with the objectives of minimizing the total maintenance costs and assuring the highest level of service to the highway users.

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REFERENCES

Forgia C. and Revetria R. 2008. “System Dynamics and Regressive Meta-Modeling Applied Methodology for Improving Management Performances in Services Industry: a Case Study in Supply Chain and Highway Maintenance”, 2008 *Proceedings of Spring Simulation Multiconference, April 14 - April 17 (Ottawa, Canada)*.

Davenport T. 1998. "*Putting the Enterprise into the Enterprise Systems"* Harvard Bus. Rev. July 12, 131.

Drucker P. F.; Ness J. A. ; Cucuzza T. G.; Simons R.; Dbvlla A.; Kaplan R.; Norton D. and Eccles R. G.; 1998. *"Harvard Business Review on Measuring Corporate Performance"*, Harward Business School Press, ISBN 0-87584-882-6.

Forrester J. W. 1961. *“Industrial Dynamics”* Pegasus Communication, 479 pp. ISBN 1883823366.

Kamath M.; Dalal N.; Sivaraman E.and Kolarik W. 2004. *"Toward an Integrated Framework for Modeling Enterprise Processes"* Communications of the ACM, March 2004/Vol. 47. No. 3 83-87.

Kaplan R. S. and Norton D. P. 2004. *"Strategy Maps: Converting Intangible Assets into Tangible Outcomes"*, Harvard Business School Press, ISBN 1591391342.

Revetria R.; Mosca R. and Forgia C. 2005. “Top Down Modeling and Montecarlo Simulation for Financial & Cost Control In Complex Projects” *Proceedings of Modelling, Identification & Control, Innsbruck A,* January.

Revetria R.; Mosca R. and Schenone M. 2005. "Improve Supply Chain Management using neural networks and regressive KPI relationship metamodels" *Proceedings of CASYS 2005, Liège (BE),* August.

Ruth M. and Hannon B. 1997. *“Modeling Dynamic Economic Systems (Modeling Dynamic Systems)”*, Springer Verlag, 339 pp. ISBN 038794849X.

Steppan D. D.; Werner J. and Yeater R. P., 1998. *Essential Regression and Experimental Design for Chemists and Engineers*, Gibsonia, PA Bethel Park, PA Moundsville, WV June.
Zrimsek B., 2002. *"ERP II: The Boxed Set"* Gartner Group, Stamford, CT Mar4.
Bellomo N.; Coscia V. and Delitala M. 2002. *On the Mathematical Theory of Vehicular Traffic Flow I.* Fluid Dynamic and Kinetic Modelling, Math. Mod. Meth. App. Sc., Vol. 12, No. 12 1801-1843.
Bianchi C. and Montemaggiore G.B 2008. Enhancing Strategy Design and Planning in Public Utilities through "Dynamic" Balanced Scorecards: Insights from a Project in a City Water Company; *System Dynamics Review* vol.24 n.2, Summer 2008.
Strohhecker J. 2007. Does a Balanced Scorecard Management Cockpit Increase Strategy Implementation Performance.
Kaplan, R. S., and Norton, D. P. 1992. The Balanced Scorecard – Measures that Drive Performance. *Harvard Business Review*, Vol. 70, 71–79.
Kaplan, R. S., and Norton, D. P. 1996. The Balanced Scorecard: Translating Strategy into Action. Boston, Mass.: Harvard Business School Press.
Kaplan, R. S., and Norton, D. P. 1996. Using the Balanced Scorecard as a Strategic Management System. *Harvard Business Review*, Vol. 74, 75–85.
Linard K.T. 2000. Application of System Dynamics to Pavement Maintenance Optimization; *Proceedings of the 1st International Conference on Systems Thinking in Management,* Geelong, Australia, November 8-10.

BIBLIOGRAPHIE

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SYSTEM DYNAMICS MODELLING OF MATERIAL FLOW OF THE PORT CARGO SYSTEM

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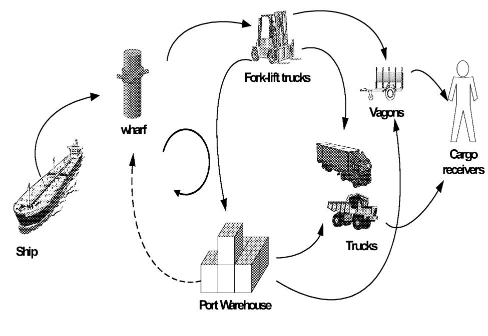
KEYWORDS

System Dynamics, Modelling, Transshipment system, Heuristic optimization, Continuous and Discrete Simulation, Port manager simulator.

ABSTRACT

Simulation Modelling, together with System Dynamics and intensive use of modern digital computer, which mean massive application, today very inexpensive and in the same time very powerful personal computer (PC-a), is one of the most suitable and effective scientific way for investigation of the dynamics behavior of non-linear and complex: natural, technical and organization systems.
The aim of this paper is to show the efficiency of the application of the System Dynamics Simulation Modelling in investigation of behaviors dynamics, one of the Port-Transshipment systems be presented with mental-verbal, structural and mathematical-computing models, and will simulate transshipment port working processes.



Structural model of material flow of the cargo

INTRODUCTION

The System Dynamics Modelling is in essence special, i.e. "holistic" approach to the simulation of the dynamics behavior of natural, technical and organization systems. Systems dynamic comprise qualitative and quantitative simulation modelling, and the concept of optimization of dynamic systems and processes is based on so call "heuristic" procedure. Meaning that on the method of manual and iterative procedure, which is automat zed with the help of fast digital computer, named "heuristic optimization".

SYSTEM DYNAMICS MODELLING OF THE PORT- TRANSSHIPMENT SYSTEM

Mental-verbal model of the Port - Transshipment System

Fundamentally, unloading of any kind of cargo can be divided in:
- ship arrival to the berthing position,
- unloading the cargo from the ship to the shore,
- transport of the cargo from the shore to the wagons, trucks and warehouses.

Unloading/loading of the cargo in port is complex dynamics process with two subsystems:
- Unloading/loading of the cargo in port (BUTUL),
- Surrounding environment (OS).

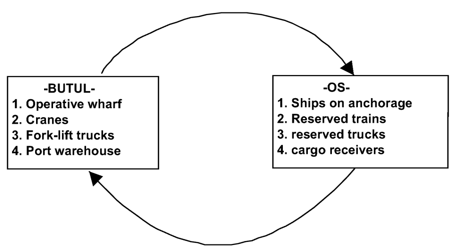


Figure1. Structural diagram of depending BUTUL and OS model of the Port Transshipment System

Subsystem BUTUL has at least four sector i.e. subsections:
1. State of occupation of the berth,
2. Number of the cranes (on the ship and on the shore), which are objective at disposal,
3. Number of the fork-lift, which are objective at disposal,
4. Warehouses (number and the area that are at disposal).

Subsystem OS have at least four sector i.e. subsections:
1. Waiting ship (on the berth or in arrival),
2. Engaged wagons capacities,
3. Engaged trucks capacities,
4. Consignee (receiver) of the cargo.

This example of PPL presents the "semi-indirect system of cargo reloading", with the preference to "maintaining the process of cargo unloading interrupted", because it is in the financial interest for the ship owner! In other words, if during the day (24h) equipment that has been reserved in advance for loading and unloading of cargo (such as crane, fork-lift truck, railway vehicle, road vehicle and space in warehouse) become insufficient, port - transport

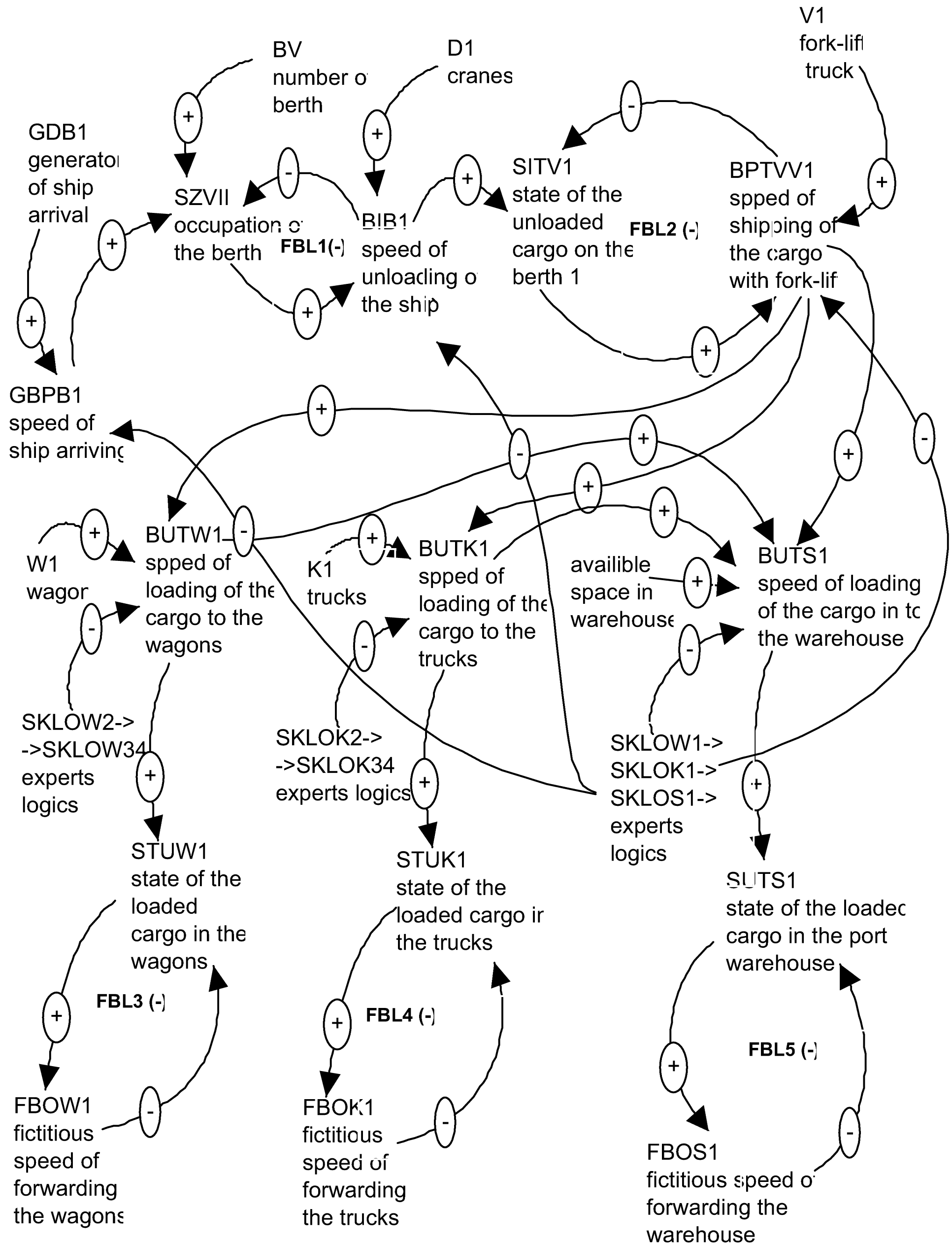


Figure 2: System Dynamics structural simulation model of the PPL-a

manager must give an order to stop the unloading of the ship. The unloading of the ship can start again when

new equipment i.e. available transport capacities are reserved (in this case railway and road vehicle).

Verbal-mental- structural simulation Models of Port Transshipment System (PPL)

"**GDB1**-Generator of ship arrival" is fictitious exogenous source of ship cargo (new arriving ship), which is possible to realize only if the state of occupation of the berth (**SZVII**) is zero i.e. completely free! It is necessary to point out that most of the ports have more than one berth, while in this elementary example the number of the berths =1. "**BIB1**-The speed of unloading the ship" depend on "state of busyness of the berth" and on number of i.e. "capacity of the crane". "The speed of transporting the cargo" from the point of unloading (Berth 1.) to the swing-gate for the loading in wagons, trucks or in port warehouse depends on the "speed of unloading the cargo" and on "number of engaged fork-lift trucks".

Material flow of the unloaded cargo in port (local transport in port) is realized from the point where the cargo is unloaded i.e. berth 1.To the loading platforms of the reserved wagons or road vehicles, or port warehouse (depending if there is free space in it).
Unloaded cargo is directed to railway platform, i.e. cargo is loaded in available railway capacities that have been reserved in advanced (24h).

If the railway capacities are fully loaded before the end of the first day of unloading, than port–transport manager gives an order to start loading in the road vehicle that have been reserved in advance.

If in limited time of one-day i.d. 24 hours of continually unloading of ship cargo all available road vehicle are used (daily reserved contingent) and new contingent of railway wagons doesn't follow, then port-transport manager gives an order to start temporally storage of unloaded ship cargo until there is free space in warehouse.

In case we don't have planed (daily reserved in advance) loading on disposal i.e. railway, road and storage capacities, port manager gives an "expensive" order, i.e. he has to stop the unloading of the ship cargo until the new railway or road transport contingent which is daily reserved in advance arrive.

In the event that new available transport capacities (wagons and trucks) arrive in time it is possible to carry on with the unloading of the ship and loading into the reserved transport in fully accordance with described expert logical decision of port manager.

Based on earlier described mental-verbal system dynamics model it is possible to determine SD diagram of flow diagrams of simulation model of the PPL-a (Figure 3.)

"Expert-logical" material flow of unloaded cargo is divided in three available and possible loading i.e. placing of the cargo that has been brought with fork-lift truck in: 1. Daily reserved railway wagon capacities, and if they aren't sufficient to load already unloaded cargo on berth 1 (24-hour working day), then: 2. In advanced reserved daily trucks capacities, and if they are also insufficient for placing the ship cargo and can cause interruption of continued process of unloading and shipping of the cargo i.e. the most expensive solution, and if it is possible this should be avoided, which is: 3. in free storage space!
In accordance with system dynamics between this three possible flows of unloaded cargo there is large degree of analogy, and it is possible to determinate structural simulation model (flow diagram) of unloading of the cargo in railway wagons.

Five reflexive circles dominate in System Dynamics structural simulation model of the PPL-a: **(FBL-a): FBL1(-); FBL2(-); FBL3(-); FBL4(-) and FBL5(-):**

FBL1(-): SZVI1(occupation of the berth) (+) ➔ (+) **BIB1**(speed of unloading of the ship) (+) ➔ (-) **SZVI1** (occupation of the berth).

FBL2(-): SITV1 (state of the unloaded cargo on the berth)(+)➔(+)**BPTVV1** (speed of shipping of the cargo with work-lift)(+)➔(-)**SITV1**(state of the unloaded cargo on the berth 1).

FBL3(-): STUW1 (state of the loaded cargo on the wagons) (+) ➔ (+) **FBOW1** (fictitious speed of forwarding the wagons) (+) ➔(-) **STUW1**(state of the loaded cargo on the wagons).

FBL4(-): STUK1(speed of loading of the cargo to the trucks)(+) ➔ (+)**FBOK1** (fictitious speed of forwarding the trucks) (+) ➔ (-)**STUK1**(speed of loading of the cargo to the trucks).

FBL5(-): SUTS1(state of the unloaded cargo in the port Warehouse) (+)➔ (+)**FBOS1** (fictitious speed of emptying of the warehouse)(+)➔(-) **SUTS1**(state of the unloaded cargo in the port Warehouse).

ELEMENTRAY STRUCTURE AND LOGICS OF IMPLEMENTATED EXPERT - INTELIGENT COMPLEX

CLIP MACRO function is often applicable, while more complex form need to be special designed, as for example complex logical variable: **SKLOWWW**, which is a part of the Sub-sector of logical management of loading the cargo in the wagon:

VUTW1K.K=(25*W1.K)/(50*V1.K)
where VUTV1= is time needed for loading the cargo in to the wagons,
W1=daily number of the wagons,
V1=daily number of the fork-lift

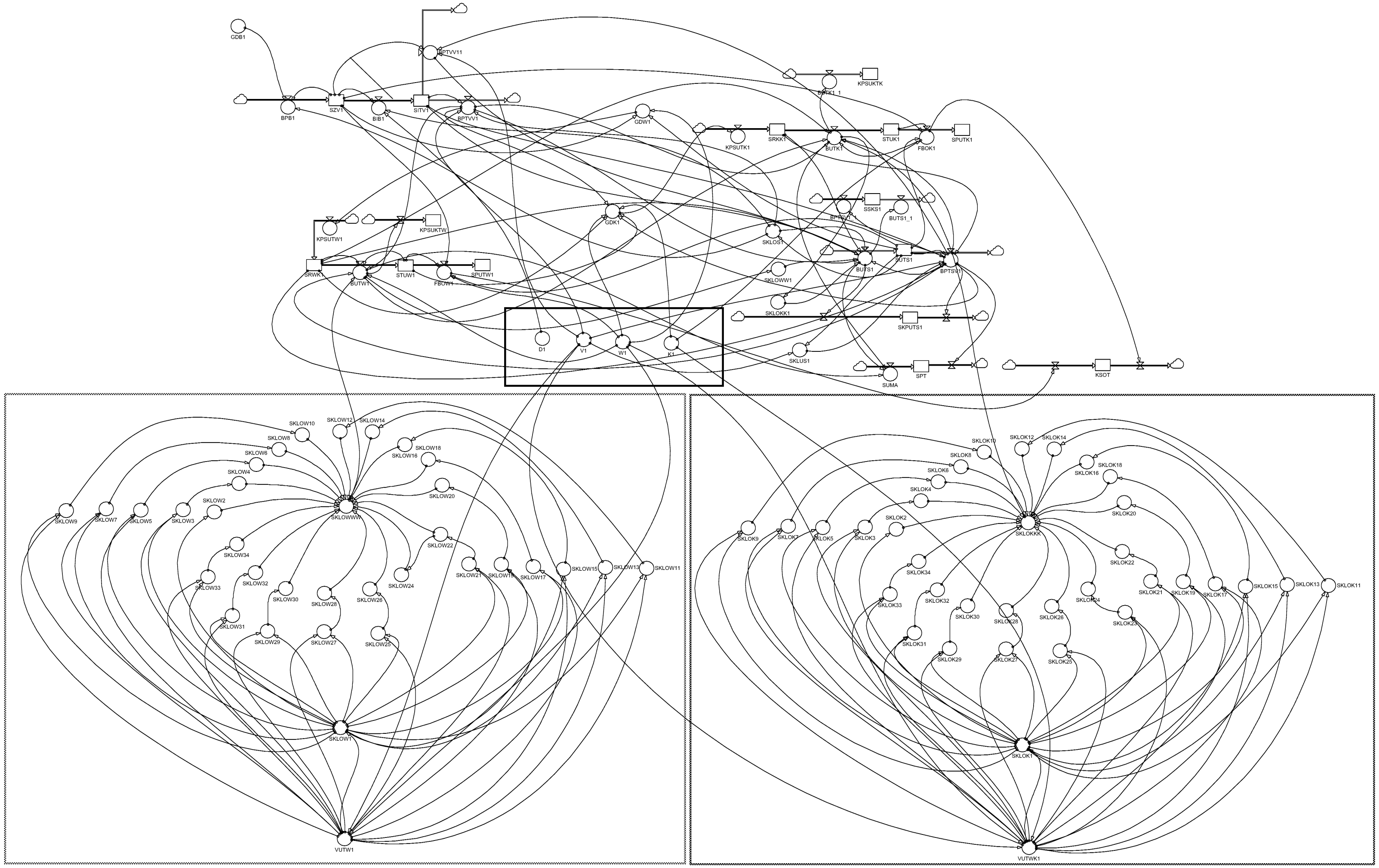


Figure 3: Complete SD diagram of flow diagrams of simulation model of the PPL-a (POWERSIM)

SKLOW1.K=CLIP(1,0,3+VUTW1.K,TIME.K)

where **SKLOW1**=is conditional logical function which determinate state of the daily contingent reserved wagons

SKLOWWW.K=SKLOW2.K*SKLOW4.K*SKLOW6.K* SKLOW8.K*SKLOW10.K*SKLOW12.K*SKLOW14.K* SKLOW16.K*SKLOW18.K*SKLOW20.K*SKLOW22.K *SKLOW24.K*SKLOW26.K*SKLOW28.K*SKLOW30. K*SKLOW32.K*SKLOW34.K

It is necessary to point out that every used equation for SKLOWWW, i.e. from SKLOW2 to SKLOW34, equally complex, and typical as follow:

SKLOW2.K=CLIP(1,SKLOW1.K,TIME.K,24)
SKLOW3.K=CLIP(1,SKLOW1.K,24+VUTW1.K,^
TIME.K)
SKLOW4.K=CLIP(1,SKLOW3.K,TIME.K,48)
SKLOW5.K=CLIP(1,SKLOW1.K,48+VUTW1.K,^
TIME.K)
SKLOW6.K=CLIP(1,SKLOW5.K,TIME.K,72)
SKLOW7.K=CLIP(1,SKLOW1.K,72+VUTW1.K,^
TIME.K)
SKLOW8.K=CLIP(1,SKLOW7.K,TIME.K,96)
SKLOW9.K=CLIP(1,SKLOW1.K,96+VUTW1.K,^
TIME.K)
SKLOW10.K=CLIP(1,SKLOW9.K,TIME.K,120)
SKLOW11.K=CLIP(1,SKLOW1.K,120+VUTW1.K,^
TIME.K)
SKLOW12.K=CLIP(1,SKLOW11.K,TIME.K,144)
SKLOW13.K=CLIP(1,SKLOW1.K,144+VUTW1.K,^
TIME.K)
SKLOW14.K=CLIP(1,SKLOW13.K,TIME.K,168)
SKLOW15.K=CLIP(1,SKLOW1.K,168+VUTW1.K,^
TIME.K)
SKLOW16.K=CLIP(1,SKLOW15.K,TIME.K,192)
SKLOW17.K=CLIP(1,SKLOW1.K,192+VUTW1.K,^
TIME.K)
SKLOW18.K=CLIP(1,SKLOW17.K,TIME.K,216)
SKLOW19.K=CLIP(1,SKLOW1.K,216+VUTW1.K,^
TIME.K)
SKLOW20.K=CLIP(1,SKLOW19.K,TIME.K,240)
SKLOW21.K=CLIP(1,SKLOW1.K,240+VUTW1.K,^
TIME.K)
SKLOW22.K=CLIP(1,SKLOW21.K,TIME.K,264)
SKLOW23.K=CLIP(1,SKLOW1.K,264+VUTW1.K,^
TIME.K)
SKLOW24.K=CLIP(1,SKLOW22.K,TIME.K,288)
SKLOW25.K=CLIP(1,SKLOW1.K,288+VUTW1.K,^
TIME.K)
SKLOW26.K=CLIP(1,SKLOW25.K,TIME.K,312)
SKLOW27.K=CLIP(1,SKLOW1.K,312+VUTW1.K,^
TIME.K)
SKLOW28.K=CLIP(1,SKLOW27.K,TIME.K,336)
SKLOW29.K=CLIP(1,SKLOW1.K,336+VUTW1.K,^
TIME.K)
SKLOW30.K=CLIP(1,SKLOW29.K,TIME.K,360)
SKLOW31.K=CLIP(1,SKLOW1.K,360+VUTW1.K,^
TIME.K)
SKLOW32.K=CLIP(1,SKLOW31.K,TIME.K,384)
SKLOW33.K=CLIP(1,SKLOW1.K,384+VUTW1.K,^
TIME.K)
SKLOW34.K=CLIP(1,SKLOW33.K,TIME.K,408)

In this global model of PTSS-a, is used more complex logical functions, for example SKLOKKK, SKLOS, which have analog structure and operation logic. This will be presented in sector of logical management of flows of the loading the cargo in the trucks, i.e. sector of the loading cargo in warehouse.

Sector of the material flow of the loading the cargo in the trucks:

SKLOKKK.K=SKLOK2.K*SKLOK4.K*SKLOK6.K*SK LOK8.K*SKLOK10.K*SKLOK12.K*SKLOK14.K*SKL OK16.K*SKLOK18.K*SKLOK20.K*SKLOK22.K*SKL OK24.K*SKLOK26.K*SKLOK28.K*SKLOK30.K*SKL OK32.K*SKLOK34

where **SKLOKKK**= is complex conditional logical function which determinate daily reserved capacities of the trucks:
UTWK1.K=(25*W1.K+20*K1)/(50*V1.K)
In model there are several logical variables of such application of CLIP function, for example:
SKLOWW1, which exclude further transshipment of the cargo in the wagons, because there is no more at the disposal;
SKLOKK, which use analogy logical mode for excluding further loading in the trucks because there is no more free;
SKLOS1, which limit further transshipment in port warehouse because they are fully occupied.

Sector of logical management of loading the cargo (in/out) the port storage:

BUTS1.KL=BPTVV1.KL*SKLOWW1.K*SKLOKK1.K* SKLOS1.K*CLIP(0,1,SRWK1.K,1E30)*CLIP(0,1,SRKK 1.K,1E-30)*CLIP(1,0,SITV1.K,1E-30)+BPTVV1.KL

In the last equation, which is application of DYNAMO MACRO CLIP function as logical limit, manager has the different operational logic: "stopping of loading the cargo in the warehouse because it is fully occupied, and still there isn't free capacities of the wagons and trucks for loading".

In model there are several logical variables of such application of CLIP function, for example:
SKLOWW1, which exclude further transshipment of the cargo in the wagons, because there is no more at the disposal;
SKLOKK which use analogy logical mode for excluding further loading in the trucks because there is no more free;
And **SKLOS1**, which limit further transshipment in port warehouse because they are fully occupied.

Scenario of the simulation model of PPL-a

This model includes putting to shore and unload of the ship on the berth, transshipment of the cargo on the wagons with subsection of logical management built in it, transshipment of the cargo on trucks also with subsection of logical management, an at the end transshipment of the cargo to the warehouse.
In this paper, cause of its largeness, we will present only zero scenarios with initial conditions:

- ship is on the berth 1,
- unloading of the ship have been started in time T=0,
- Transshipment of the cargo with cranes, and the number of cranes are D1= 2+STEP(2,47)-STEP(2,119), i.e. the capacities of the cranes are 50*D1
- Transshipment of the cargo on the fork-lift, and the number of fork-lift are V1= 2+STEP(2,47)-STEP(2,119), i.e. the capacities of the cranes are 50*V1
- Transshipment of the cargo with fork-lift from the berth to the gate and transshipment on the wagons, and the number of wagons are W1= 56+STEP(40,71)-STEP(40,119)
- transport of the cargo on the trucks, and the number of trucks are K1= 20+STEP(10,47)-STEP(10,95),
- transport of the cargo in the warehouse, and capacities of the warehouse are 54000.

System dynamics simulation modelling results

Graphic results of simulation:

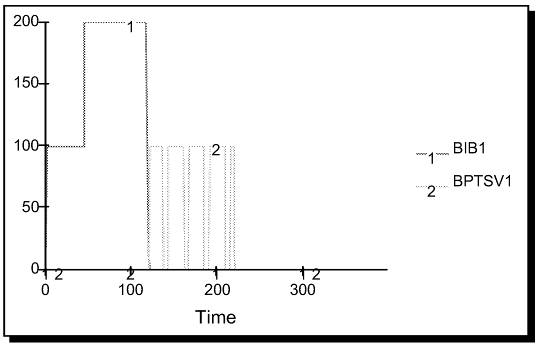


Figure 4: Speed of unloading the ship-BIB1, Speed of shipping of the cargo to the warehouse-BPTSV1

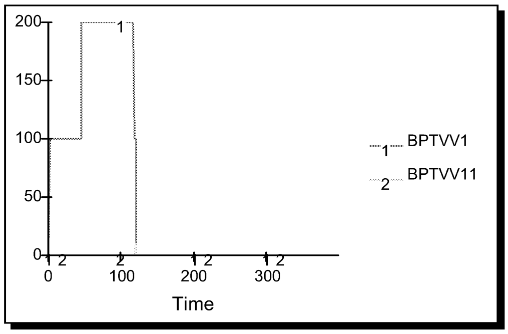


Figure 5: Speed of shipping of the cargo with fork-lift from the berth1 to the platforms for loading on the wagons, trucks or warehouse-BPTVV1, Speed of shipping of the cargo with fork-lift from the berth 1 in the case that SITV1 is multiple of the number of the fork-lift-BPTVV11

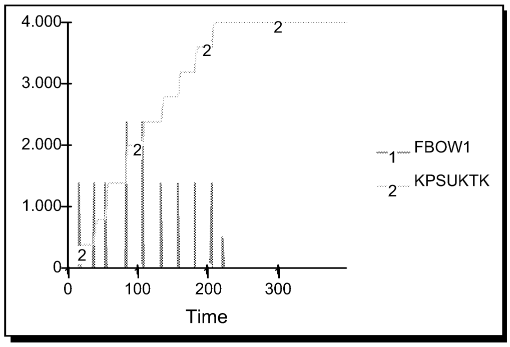


Figure 6: Fictitious speed of forwarding the wagons in 24 H-FBOW1, Cumulative display of the state of the loaded cargo on the trucks-KPSUKTK

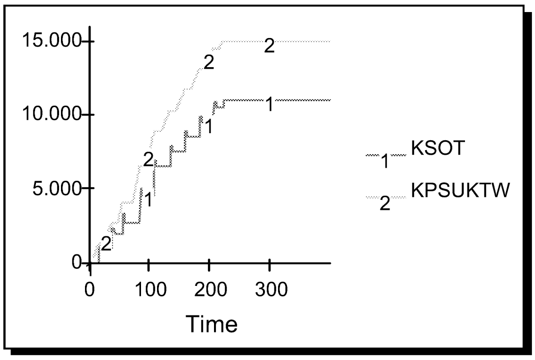


Figure 7: Cumulative display of the state of the loaded cargo on the wagons-KPSUKTW, Cumulative book-keeping state of the shipped cargo-KSOT

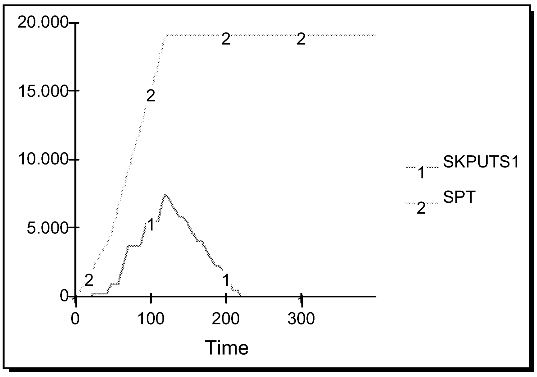


Figure 8: State of the cumulative display of the loaded cargo to the warehouses-SKPUTS1, Current state of the cargo-SPT

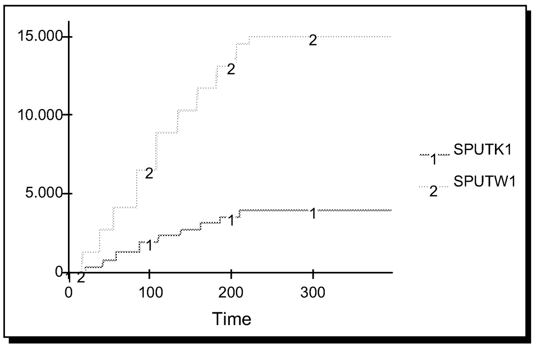


Figure 9: Summary display of the loaded cargo on the trucks-SPUTK1, Summary display of the loaded cargo on the wagons-SPUTW1

Based on presented simulation dynamics of behavior of model in complex scenario it is possible to conclude:

- It is possible to simulate daily speed of unloading the ship and shipping the cargo from shore using STEP function, also it is possible to simulate daily need for trucks and wagons, and in that way avoid necessary wait for new trucks and wagons and also to avoid stoppage of unloading the ship or sipping the cargo from the port warehouse.
- Also, application of STEP function enable to control all relevant data, daily and current data, follow the unloading and shipping the cargo, state of the cargo at the port warehouse, available capacities in port warehouse, etc...
- Based on obtained results it is possible to analyze state of the system at any wonted moment in time.

CONCLUSION

The application of System Dynamics Simulation Modelling Approach of the complex marine dynamic processes, which the authors, together with their graduate students, carried out at the Maritime Faculty University of Split - Croatia seven years ago, revealed the following facts:

l. The System Dynamics Modelling Approach is a very suitable software education tool for marine students and engineers.
2. System Dynamics Computer Simulation Models of marine systems or processes are very effective and successfully implemented in simulation and training courses as part of the marine education process.

In this short presentation are given all necessary information for expert and possibility to acquire additional information about the same system in fast, scientifically based way of investigation of complex system.

Which means?

" Do not simulate behaviors dynamics of complex system using so called "black box" approach, because practice of education and designing of complex system confirmed that is better to simulate using so called "white box" approach, e.g. System dynamics Methodology Approach!"

Instead of conclusion, it should be useful to quote a well-known Chinese proverb:

"When I hear, I forget.
When I see, I remember.
When I do, I understand".

REFERENCES

Coyle, G. R. 1996. "System Dynamics Modelling", Chapman & Hall, London.

Munitic, A.1989. "Application Possibilities of System Dynamics Modelling, System Dynamics, Edited by Susan Spencer and George Richardson, Proceedings of the SCS Western Multiconference, San Diego, California, A Society for Computer Simulation International, San Diego, USA.

Zelenika, R., Jakomin, L. 1995.. "Modern Transport Systems, in Croatian", Economic Faculty-Rijeka, Croatia

Dulčić, A. 2001. „Upravljanjem razvojem Turizma", Mate, Zagreb.

Munitić, A. 1989. „ Kompjuterska simulacija uz pomoč sistemske dinamike, Brodosplit, Split.

Pidd, M. 1997.: "Computer Simulation in Management Science", Wiley, New York.

Čerić, V. 1993.: *Simulacijsko modeliranje*, Školska knjiga, Zagreb.

Waren, K. 2002. "Competitive Strategy Dynamics", John Wiley & Sons,Chichester, Englaand.

Pidd, M. 1997. "Computer Simulation in Management Science", Wiley, New York.

Richardson, G.P. 1986 „Problems with causal – loop diagrams", Sistem Dynnamics Review 2:158-170.

Garcia, J.M. 2006 „ Theory and practical exercises of system dynamics", First edition in English March.

Barlas, Y. 1996. „Formal aspects of model validity and validation in system dynamics, System Dynamics Reviea, Vol, 12, No.3, 183-210.

Coyle, R.G. 1977. „Management system dynamics",John Wiley, New York.

Randers, J. 1980. „Elements of the system dynamics method", MA Productivity Press,

Sterman, J. D. 1985. Deterministic chaos in an experimental economic system", Jurnal ofEconomic Behavior and Organization 12.

Forrester J.W., 1984. „ Urban Dynamics", MIT, Cambridge, Massachusetts, and London, England, Seventh printing, Copyright 1969 by MIT

Forrester J.W. 1980." Principles of Systems", MIT Press Cambridge, Massachusetts, and London, England, Second Preliminary Edition, Ninth Printing, Copyright 1968 by Jay W. Forrester

Lyneis, M., James 1982. "Corporate Planning and Policy Design: A System Dynamics Approach" MIT Press Cambridge, Massachusetts.

Waren, K. 2002. "Competitive Strategy Dynamics", John Wiley & Sons, Chichester, England.

BIOGRAPHY

ANTE MUNITIĆ received a double BS in 1. Electro-Energy Engineering and 2. Electronic Engineering, and a MS in Electronic-Operating Research at the University of Split, Croatia, and a Ph.D. degree in Organization Science (System Dynamics) at the Belgrade University, Yugoslavia. All degrees were earned while actively engaged in teaching at the university. He is now Full Professor Doctor of the Computer & Informatics Science and is a Maritime-Faculty University Professor of the following courses: 1. Computer science, 2. Marine Systems and Processes Management Modelling (System Dynamics) and 3. Marine Integral Information Systems. His research interests are 1. Researching System Dynamics Methodology, 2. Relative System Dynamics (optimization), 3. System Dynamics Analogizes, and 4. Chaotic System Dynamics. He is a member of the Society for Computer Simulation and the System Dynamics

COMPLEX SYSTEMS SIMULATION

AIRCRAFT CONTROL STRATEGIES IN A DISTRIBUTED COOPERATIVE MISSION SIMULATION ENVIRONMENT

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Aircraft Control, Cooperative Missions, Simulation, UAVs.

ABSTRACT

Simulation tools have gained an important role in scientific, academic and even business communities, allowing for time- and cost-effective research and development of solutions, more appealing training and learning activities or providing better tools for decision support. This is particularly true in the aviation and aeronautical areas. In this paper, we compare different control strategies for specified high-level maneuvers in aircraft within a simulation environment, each aircraft represented by an independent agent, focusing on communication necessities and maneuver effectiveness. A brief overview on the project's overall architecture and an outline of structured experiences, also known as missions, available within the simulator, show the potentials of the platform for the more comprehensive goals of this project, allowing the definition and execution of cooperative missions by a team of agents, such as surveillance and search & rescue operations.

INTRODUCTION

Simulation tools are widely used in several fields of research, providing researchers with the means to develop their work in a cost- and time-effective manner. These and other advantages of simulation environments have led to a significant growth in their general use by the scientific community, as well as in several business areas, supporting decision-making processes, planning, training, and many other tasks. Alongside professional simulation tools, designed specifically to the research purpose they are used in, game engines and gaming tools are being adopted more and more by the scientific community as serious tools in their work. An area of knowledge known as serious gaming explores the use of games and game-like applications in training or learning, or using them as decision support tools, to improve business processes. Not only the entertainment organizations use of these new applications, but also governmental and military organizations, mainly for training purposes, be it in the leadership and management areas, or in a more technical approach, using primarily simulation tools (Stone 2005).

One field of research where simulator tools are extensively used is aviation. In fact, simulators used in this area range from multi-million dollar full hardware and software simulators used to train professional pilots to freely available flight simulators, which have been used mainly for entertainment purposes and by aviation enthusiasts. As an example, one of the world's most famous simulators, NASA's VMS (Vertical Motion Simulator), is a full simulator capable of six degrees-of-freedom movements, housed in a ten-story building in Ames Research Center, California (Danek 2003; National Auronatics and Space Administration 2008). This simulator is capable of providing different simulation experiences, thanks to the ICAB (Interchangeable Cab) feature, which allows a modular interior of the simulation cabin, presenting the pilot with different cockpit interfaces with the simulator. An impressive 1300 variables can be retrieved from the simulator, allowing for thorough data analysis of simulation sessions. This simulator has been used for pilot and astronaut training but also in cooperation with other entities (Tran and Hernandez 2004). On the other end, flight simulators such as FlightGear (an open-source flight simulator) are available for download at no cost or at a reduced price. Some of these low-cost flight simulators have, in the latest years, achieved a high level of realism, both in the simulation of aircraft systems, kinematics and weather conditions, and also in the visualization of all these aspects with a realistic and detailed terrain. Some of them have been certified by the FAA (Federal Aviation Administration) for pilot training, when used in conjunction with the proper hardware simulator.

In the recent years, simulators in several areas have evolved into more complex systems, and in many cases a multi-agent system approach has been adopted. In these systems, the participating entities are represented by independent agents, which in turn communicate with each other, coordinating information and actions. In the aeronautical area, this approach has also been adopted, usually with each agent representing one aircraft (or even several agents representing the several systems of one single aircraft, if a more detailed simulation of a specific system is required). Such systems are used to develop new strategies to solve problems such as collision avoidance among UAVs (Unmanned Aerial Vehicles) (Samek at al. 2007), formation flight or fault tolerance (Zhang et al. 2005), among others. These systems should also address the interaction with human beings, allowing for a real-time awareness of the situation and the possibility to define missions, or even to override decisions made by the agents (Schurr et al. 2005).

The authors' vision is to make use of such a system in order to develop strategies to use in cooperative missions, such as surveillance and search & rescue scenarios. This paper focuses on control strategies for aircraft within the simulation environment, and their effectiveness in terms of both communication necessities and maneuver smoothness and accuracy. Three distinct strategies were tested to control different aircraft, and the experimental results were analyzed as to assess which of the methods is most suited to use in the simulator. As to provide with a more comprehensive context on the project, the following subsection summarizes the steps that were previously taken.

Background Context

The main goals of the overall project are to use a simulation platform as a basis for the design and cooperative execution of joint missions. These missions are to be performed by a team of heterogeneous vehicles, including planes, helicopters, land vehicles, and submersible vehicles, capable of communicating with one another, in order to coordinate their actions. The applications of such a system are diverse, including surveillance (forest surveillance that provides an early fire detection system, coastal and border patrol, in order to detect and track illegal activities, such as smuggling, urban observation that would detect dense traffic patterns, preventing larger traffic jams, and many other applications), reconnaissance and target tracking (especially useful in military operations and law enforcement activities, to provide real-time valuable information about enemy movements, or to follow a fugitive until apprehended by competent entities), aiding in search & rescue operations, and many other applications.

The project's envisioned architecture incorporates the chosen simulator, a number of external agents, each representing one vehicle within the team, as well as some valuable peripheral services, such as a monitoring application, capable of real-time vehicle tracking, as briefly mentioned in the results section, simulation logging that enables mission replay and further analysis, and an interface with external modules, for interaction with real vehicles.

Previous work on this project included a thorough study of simulation platforms, which resulted in the choice of Microsoft Flight Simulator X (FSX) as the platform to be used. This was based on the platform's admirable graphical features, simulation of aircraft dynamics and interaction with the environment, possibility to inject failures in certain aircraft systems and sensors, excellent application programming interface documentation, with hundreds of simulation variables that can be read and written to, hundreds of events that can be sent to the simulator, and many other features (which allow an external application to interact with the simulator in real-time), as well as the available mission system, with its outstanding possibilities.

Structured experiences, or missions, as they are commonly known, are a feature of FSX that allows regular users to have a different, interactive experience of flight, with measurable goals. FSX includes numerous missions, ranging from tutorials that teach the user how to fly an aircraft, to racing missions, simulating the Red Bull Air Race environment, as well as several transport or rescue operations, among others. The mission system allows for the definition of objects, areas, triggers and actions that can be linked to work together in an orchestrated manner, producing diverse, realistic and complex missions (Stark 2007). Microsoft has also already recognized the advantages of simulation in various business areas and the potential of these structured experiences, and is commercializing the engine behind FSX as a new enterprise-oriented product, called ESP (Microsoft 2008). There are numerous applications of this technology, and several high-profile companies have already signed partnerships with Microsoft for the use of ESP, such as FlightSafety International, SAIC, Lockheed Martin and Northrop Grumman (Microsoft 2008; Training & Simulation Journal 2008). These companies, as well as others that use this product, will be able to use it to train staff (not only piloting skills, but also management skills for airline companies and airports, for instance), learning, research or decision support – by simulating different scenarios, the most favorable one can be identified, problems and design flaws can be corrected, business processes can be improved.

Autopilot Systems

Although autopilot systems are usually associated with aircraft, they can be used in any kind of vehicle, including boats, cars, or even missiles. In this paper, and in our work, the focus is on aircraft autopilot systems. There is a variety of autopilots commercially available for small unmanned aircraft, usually comprised of light-weight hardware to connect to the aircraft and a control station, also often including some software to interact with the system. These autopilots range from simple one-axis controllers to full three-axis systems, including redundant processors, sensor diagnostics and failure tolerance, medium- to long-range communication system and many other useful features when dealing with payloads. Integration and testing of autopilot systems with the aircraft has to be carefully executed, as to calibrate the system to the aircraft in question (Erdos and Watkins 2008). Commercial aircraft also feature autopilot systems, which can control the aircraft from takeoff to land without human intervention (these systems are, however, usually only used during the leveled part of the flight, and during landing, when visibility conditions are below certain limits). These full autopilot systems use redundant computers to ensure that control decisions are correct, and provide a more stable flight than human pilots would, lowering fuel consumption at the same time.

The rest of this paper is organized as follows. In the next section, the three approaches that were compared are explained in more detail. Section three presents the settings for the experiments that were conducted and section four presents the results that were attained, comparing the approaches. Finally, in the last section, some conclusions are withdrawn and lines of future work are presented.

CONTROL STRATEGIES

In this section, the three devised control strategies are presented and briefly compared. The first approach consists on direct manipulation of the aircraft controls, such as aileron and elevators through a PID controller. The two other approaches use auto-pilot systems. The second one makes use of the auto-pilot system available to actual pilots, delegating the handling of aircraft controls to the system. The third approach uses the AI auto-pilot, used by the simulator to perform automated flights. The differences between these methods and the specifics of each one are detailed in the following subsections.

PID Controller

The first approach to controlling an aircraft within the simulation environment is to recreate the actions of a pilot when attempting to follow a certain route. This was accomplished by direct manipulation of the main controls of the aircraft, namely the throttle, aileron and elevator. The throttle control is used to control the speed of the aircraft – if set to full throttle indefinitely, the aircraft would accelerate into a speed above the maximum speed at which it is safe for the aircraft to fly. The elevator control is used to control the pitch angle of the aircraft (sometimes referred to as angle of attack, pitch measures the nose up or down angle of an aircraft), and, when used in conjunction with the throttle control, it allows to control the altitude of the aircraft – in order to climb, the elevator must be set to a positive value, and the throttle should be set to full throttle; in order to descend, the elevator must be set to a negative value, and the throttle should be set to idle. The aileron control is used to control the bank angle of the aircraft (also called roll, it is the angle of rotation of the plane about its longitudinal axis). In order to make a turn, the aircraft rolls toward the inner part of the desired turn. By using these controls together, higher-level maneuvers are executed.

In order to handle these aircraft controls, a PID controller was used. A PID controller is a generic control loop feedback mechanism that attempts to correct the error between a measured variable and the desired value by calculating a corrective action that can adjust the process accordingly. It is a well-known controller from the control theory field, and has been used successfully in the industry for many years. Its numeric implementation consists on the evaluation of Equation (1), where e is the difference between the reference value and the feedback measured value, τ is the time in the past contributing to the integral response and K_p, K_i and K_d are the proportional, integral and derivative gains, respectively. The proportional term adjusts the output signal in direct proportion to the error, the integral term is proportional to both magnitude and duration of the error, and the derivative term measures the approximate rate of change of the error. Tuning the gain factors of the PID controller is an important step, to assure optimal values for the desired response (Skogestad 2003).

$$output(t)=k_p e(t)+k_i\int_0^t e(\tau)d\tau+k_d\frac{de}{dt} \quad (1)$$

For this approach, the control agent communicates with the simulated aircraft at a given rate, in order to send the current values, calculated with the PID controller. Ideally, the communication would be uninterrupted, since continuous adjustments to the aircraft controls should be made, to maintain the desired flights settings. However, the simulator only sends and accepts values once per simulation cycle, and to send data at a higher rate would be a waste of processing time. Moreover, one has to account for communication latencies that make it difficult to receive data from a given simulation cycle and to send the corrective values that reach the simulator in time for the following cycle. There is a simulation variable that is modified for each of the three aircraft controls that are manipulated by the controller, and other variables that can be read in order to assess the current position, speed and attitude of the aircraft, used in the calculations as mentioned above. In order to make a banked turn with a given radius (for circling maneuvers, for instance), some additional information has to be taken into account. The radius of a banked turn is given by Equation (2), where v is the true airspeed of the aircraft, g is the acceleration due to gravity and θ is the bank angle of the aircraft.

$$R=\frac{v^2}{g\tan\theta} \quad (2)$$

Given Equation (2), one can determine the necessary bank angle to generate a banked turn with a given radius at a given speed, as demonstrated by Equation (3):

$$\theta=\tan^{-1}\left(\frac{v^2}{gR}\right) \quad (3)$$

Autopilot

In this approach, the autopilot features of aircraft are used. Autopilot systems assume various forms, ranging from simple wing-levelers to complete systems, capable of controlling an aircraft from takeoff to land. Most modern aircraft feature altitude, heading and speed controls, allowing the pilot to set the desired values for each feature. The altitude control manipulates the elevator and throttle (if auto-throttle is available) in order to reach and maintain a certain altitude. The heading control manipulates the aileron in order to make a banked turn until the desired heading is reached, and the speed control automatically adjusts the throttle to maintain the desired airspeed. This approach uses the available autopilot systems as a pilot would, to adjust the aircraft's course to the desired settings.

There is a straightforward limitation to this approach, which is the necessity for the presence of an autopilot system. In fact, many smaller, older aircraft do not possess an autopilot system, or it is only comprised of the already mentioned wing-levelers, capable only of maintaining a straight level flight (but not to change altitude, heading or speed). The authors, however, feel that this limitation does not impose a major problem, since there are several commercially available autopilot systems for small unmanned aircraft, such as the Piccolo autopilot system, from CloudCap Technology (CloudCap Technology 2008), which are usually used for the type of aircraft that are intended to be used in real-life experiments.

With this approach, there are limits that need to be taken into account when planning the maneuvering scenarios. For instance, the autopilot system limits for the bank angle. As previously seen, the bank of a plane influences the radius of the curve, and as such, a minimum radius for turns is calculated based on the aircraft cruise speed and maximum bank angle at the beginning of the simulation, and that minimum value is enforced on maneuvers that require the plane to move in a circular fashion.

Since these systems do not allow for a direct control of the bank angle, a circular path is a bit more complicated to achieve. For circular paths, several points along the turn were calculated, and used as a basis for heading determination. By providing the aircraft with regular changes in the desired heading, a smooth circular path is achieved. The number of points in the path is directly proportional to the difference between the desired radius and the minimum radius – if the desired radius coincides with the minimum radius at the current aircraft speed, there is no need to use more than two alternating points to update the heading control. As with the PID approach, this one also requires frequent communication with the aircraft, in order to send the desired values for the autopilot system.

AI Autopilot

The third approach makes use of the AI autopilot within the simulator to control the aircraft. This AI autopilot can be used in every aircraft, independently of the existence of an autopilot system such as the one described in the previous approach. It is used by the simulator to guide the generated air traffic from departure to arrival airports.

As with the previous approach, this autopilot also features limitations, namely the bank angle. When an autopilot system is available, the maximum bank angle is used to calculate the minimum radius for a turn, just as in the previous approach. When no autopilot system is present, the default value of twenty-five degrees is used – this is the most common value for autopilot systems, and experimental activities have demonstrated that this is also the most usual value for this AI autopilot. This approach has, however, a few more limitations. In this case, all navigation is based on waypoints, which specify not only the latitude/longitude/altitude coordinates of the desired point, but also the desired speed or throttle percentage to be applied. Having this limitation in mind, and similarly to the previous approach, several points have to be calculated and fed to the aircraft for circular paths. This approach, however, does not require frequent communication with the aircraft – all points of a maneuvering sequence can be sent at the same time, in a waypoint list structure. The exception to this behavior is the existence of loops in the path – if a portion of a path is to be repeated until some external event occurs (such as human intervention), the waypoints that represent that loop have to be sent at the beginning of that loop, with a flag indicating that after the last waypoint, it should return to the first; when the loop is to be broken, the remaining waypoint must then be sent, replacing the previous ones.

High-Level Maneuvers and Waypoint Computation

In order to compare these methodologies, some high-level maneuvers were considered, namely the 'go to point' instruction, the circle and the helix maneuvers. Additional instructions could be issued to the aircraft, including desired airspeed, heading or altitude and target vehicle interception. These additional instructions would force the aircraft to accelerate or decelerate to attain the desired airspeed, turn and maintain the desired heading or climb or descend in order to reach and maintain the given altitude. The target interception instruction provides the aircraft with the most probable point of interception with the target vehicle, if possible (aircraft and target vehicle speed, distance and heading are used to determine if interception is possible), updating the interception point every few seconds. The authors believe the three first instructions to be sufficient to test the efficiency of vehicle control, since others can be achieved by using the first ones or similar method.

The 'go to point' instruction has three logical parameters: latitude, longitude and altitude of the point to be reached. The circle maneuver is defined by the central point (latitude, longitude and altitude), the radius and the number of laps, if not to loop indefinitely. The helix is defined by a central line (latitude and altitude), the initial and final altitudes, the radius and the number of laps. As previously mentioned, the radius for the last two maneuvers is conditioned by the aircraft's maximum bank angle and airspeed.

In order to compute the points used by the two last maneuvers in the two approaches that use autopilot systems, some considerations were made. First, the number of points is directly proportional to the difference between the intended radius and the aircraft minimum turn radius. Second, and most importantly, the order in which those points are presented can deeply influence the path of the aircraft. For a smoother transition, a tangential approach to the virtual circle is preferred, especially when the circle has a radius closer to the minimum turn radius. The following algorithm was used to determine the first point and the order of the remaining points: a list of points is determined for the given radius, ordered as to form a circle; the distances between the aircraft and the points are determined; the first point is the $(N/2)^{th}$ closest point to the aircraft, N being the number of points in the circle; the second point is the point further away from the aircraft, chosen among the two points that are adjoining the first point in the original list of points. The remaining points are determined according to the order in which they were initially determined. Figure 1 illustrates the choice of the first and second points in a hypothetical 8-point circle and subsequent direction of turn.

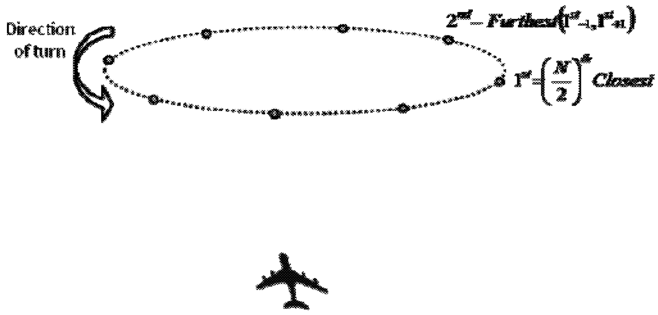

Figure 1: Waypoint Determination

The current aircraft position is used if the circle or helix maneuver is to be executed immediately; if the maneuver is to be queued after another, the final point of the previous maneuver is used. Also, the aircraft position to consider may be adjusted to a position where the aircraft's heading is towards the region of the desired maneuver, considering a turn with the minimum radius at current speed.

EXPERIMENTAL SETTINGS

In this section the experimental settings for the conducted experiments are presented. As already mentioned, FSX was the chosen simulator. Different experimental conditions were recreated for each control approach, with three main controllable variables – aircraft type, weather conditions and maneuver sequence. Different aircraft types were used to assess how generic the approach was, or if it had limitations, namely regarding the size or type of aircraft. A total of three distinct aircraft were used in the experiments, which include a Piper J-3 Cub (a single-engine two-seater light aircraft, with a maximum speed of 74 knots), a Beechcraft Baron 58 (a twin-engine six-seater with a cruise speed of 200 knots) and a Bombardier Learjet 45 (a twin-engine-jet nine-seater with a cruise speed of 464 knots). Since this project is to be used with small to medium-sized aircraft, the authors felt no need to conduct the experiments with larger aircraft. Although the Piper J-3 Cub does not possess an auto-pilot system, the authors think it was important to include this aircraft, as to test the performance of the two other approaches on a smaller, slower plane. Different weather conditions were used to test the control performance under adverse conditions, and how flexible the approach was to the existence of uncontrollable and unpredictable external factors. The experiments were conducted under two different weather conditions – fair weather and gray and rainy. The authors felt that harsher weather conditions would not be necessary, since the intended aircraft would not fly under more adverse weather conditions. Different high-level maneuvering sequences were also tested, as to assess how the approach would handle maneuver transition and how smooth the final flight would be. Basic high-level components were used to compose the three maneuvering scenarios used in the experiments. These high-level instructions include a 'go to point' command, indicating that the aircraft should pass through a given latitude/longitude/altitude point; circle, indicating that the aircraft should circle a given point with a given radius, either one time or continuously; helix motion, either climbing or descending from one initial altitude to a final altitude though a series of turns around a central point.

All experiments begin with the selected aircraft stopped in the end of a runway (34R) of the selected airport – Seattle-Tacoma International – with idled engines, facing the runway. The first command of the maneuvering sequence is always a ‘go to point’ command, with a point directly in front of the aircraft, approximately 500 feet above the runway, in order to assure both a smooth takeoff and that the aircraft attains its cruise speed. Slight variations in the scenarios were introduced for the three aircraft, due to their different cruising speeds. As already mentioned in the section above, the radius of a banked turn is proportional to the square of the velocity of the aircraft, and hence, a larger radius was used for faster aircraft in the circle and helix commands. As a result, other commands were also modified in terms of longitude/latitude, in order to accommodate for the larger radius of these commands, as to maintain the overall proportions between the several control points.

RESULTS

In this section, the results that were attained through the experiments that were conducted, and as described in the previous section, are presented. For a more structured arrangement, the results are divided into two categories – communication necessities and maneuver effectiveness.

Communication Necessities

The first dimension that was analyzed is communication requirements. In this subject, the third approach is far less demanding. While both the first and second approaches need to communicate with the aircraft at regular intervals, the third approach only communicates in the beginning of the experiment and, in the case of the third scenario, two other times, due to existence of a user-controlled loop.

In a more detailed view, the first approach needs to send elevator, throttle and aileron data at regular intervals. In the experiments that were conducted, the values were sent every second. Although this was more than enough for the simulated experiments, it is believed that this kind of approach would require, in real live, more frequent adjustments to the aircraft controls to produce a stable flight. The second approach also sent data at regular intervals, even though a higher two-second interval was used. The data sent in this approach consists of heading, speed and altitude values for the autopilot knobs. With the third approach, and considering the mentioned exception of user-controlled loops, all data is sent before-hand. This data consists of a list of a waypoint-describing structure, containing the latitude, longitude and altitude of the point, desired speed or throttle and some flags, indicating how the waypoint should be interpreted.

Maneuver Effectiveness

Maneuver effectiveness was evaluated on a more subjective level, by analyzing and comparing the paths the aircrafts flew through. On a more immediate level, the experiment flights were accompanied in real-time, using both the simulator’s graphical interface and the developed monitoring tool. This tool uses collected aircraft data as well as information about the determined waypoints to display the current position and orientation of the aircraft, as well as the positions and order of the various waypoints. This was done using the Google Maps and Google Earth APIs, to render the desired icons on top of the two- or three-dimensional representation of the surrounding environment in a plugin using an embedded web browser. Figure 2 shows the developed monitoring application, with the several waypoints that define a circle, and a visible aircraft between points five and six.

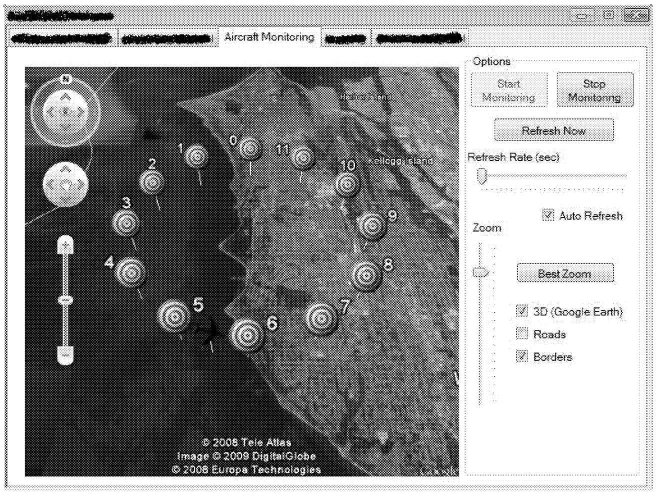

Figure 2: Monitoring Tool

In addition to this immediate and inaccurate visual inspection of aircraft data, information about aircraft position, speed and attitude was collected at regular intervals and stored in a log file. The developed logging application then converted this information into two formats: KML format (Keyhole Markup Language), and CSV format. The first format, KML, allows for a visual inspection of the paths in an application such as Google Earth. Figure 3 shows the result of an experiment conducted for the first scenario. The CSV format can be imported to an external application, such as Microsoft Excel, which was then used to generate three-dimensional graphs, as to facilitate in a further, more thorough, inspection of the flight paths without additional visual distractions.

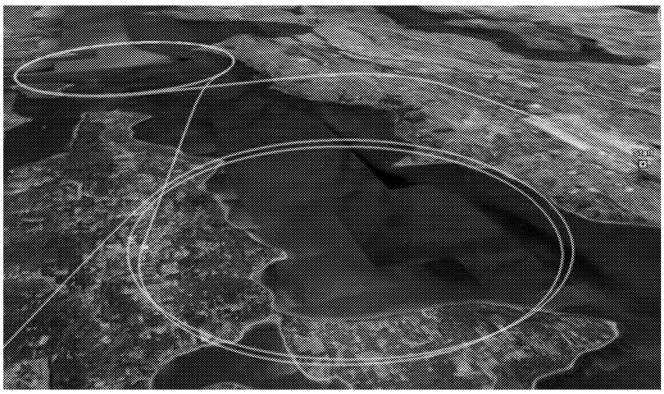

Figure 3: Google Earth Preview of Flight Path

Figure 4 shows the results from the experiment above in a three-dimensional graph. A more detailed assessment of the efficiency of the control approaches can be made with these graphs, especially in the altitude dimension.

As previously stated, experiments were conducted with three distinct aircraft, using three distinctive scenarios and under two different weather conditions. As to assess the influence of each of these three factors in the tested approaches, the results were evaluated by grouping experiments with two common variables and analyzing the results in respect to the third one. Considering different aircraft, and as previously stated, the second approach could not be tested in the smallest aircraft, since there is no autopilot system available to the pilot. The first aircraft had a similar performance with both the first and third approaches. The second aircraft showed a slightly better performance when using the first and third approaches, compared to the second one. The third and largest aircraft had a comparable performance for all three approaches. Regarding the three distinct scenarios, there weren't any significant differences among the three approaches. The three scenarios diverged in the complexity of the intended course, each scenario adding more maneuvers and decreasing the space between maneuvering areas. This caused the aircrafts to make more abrupt turns, but all approaches handled this without posing any problem. In respect to the influence of weather conditions in maneuver effectiveness, they were similar with all three approaches. The resulting paths were a bit more unstable, presenting more variations in altitude and in some cases widening the radius of the circling maneuvers. In the cases, when this happened, the second and third approaches were more susceptible to erroneous maneuvering. In three cases, when using the third scenario, two with the second approach and one with the third approach, the aircraft performed a full circle in order to pass through a point it had previously missed. As for the first approach, the influence of deteriorating weather conditions was also felt in the form of course shifting. This was particularly visible with smaller aircraft, performing circle maneuvers, each lap slightly warped in the direction of the wind.

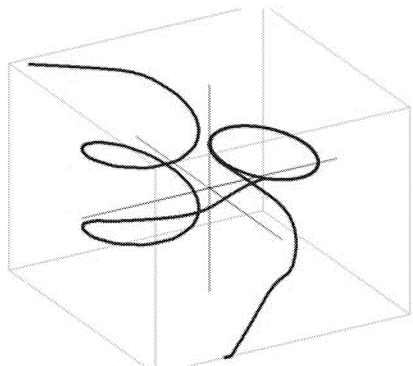

Figure 4: Three-Dimensional Graph of Flight Path

CONCLUSIONS AND FUTURE WORK

In this section, some conclusions that can be withdrawn from the tested approaches and the experimental results are presented. Also, some lines of future work are presented.

From a more theoretical point of view, one can draw some conclusions from the devised approaches. The PID controller approach is a generic method, which works with any aircraft that has the necessary controls (throttle, aileron and elevator). However, it requires an almost constant communication with the aircraft, in order to send the current values. Moreover, most aircraft now have some sort of auto-pilot system, which performs the same calculations as the PID controller, and, most probably, in a more effective manner, having the gains already tuned for the specific aircraft. The auto-pilot approach is not a general method, as can be seen from the aircraft chosen for the experimental activities – not all aircraft have auto-pilot systems. Moreover, it also requires an almost constant communication with the aircraft, just as the first approach. It does, however, make a lot less calculations in the control agent side, leaving them to the auto-pilot system. The third approach is also a generic approach, given that any aircraft can be used with the AI auto-pilot system. It is far less demanding in what concerns to communications requirements, since it only needs to communicate once. It is, however, a communication burst, with far more data to be transmitted. Additionaly, substantial waypoint calculation has to be previously performed by the control agent.

From a more practical point of view, one has to consider the results that were attained through experimentation, as presented in section five. In respect to maneuver execution effectiveness, there are no significant differences among the three approaches. However, and although the second approach is viable when dealing with real aircraft, as already explained in section 3.2, it is not practical to use that approach in the simulated environment, since it would exclude some aircraft from being used. The use of different aircraft does not seem to influence the performance of the approaches, with the only visible impact being the increase of the turn radius caused by the increase of the aircraft speed. Also, all approaches seem to be equivalently affected by deteriorating weather conditions, although the autopilot-based approaches are more susceptible to missing one waypoint. This can, however, be easily corrected if one increases the distance at which the aircraft is considered to have reached a waypoint when the weather conditions deteriorate. Regarding the communication requirements, one has to conclude that the third approach, based on the AI autopilot, is the best approach, since it does not require a constant communication with the aircraft, and therefore the possibility of error due to a failure in the communication with the aircraft is reduced to a minimum. The first two approaches are more susceptible to errors caused by a communications malfunction, which could lead to an erratic maneuver performance, or even to more serious and unpredictable consequences, if the communication breakdown extents for a longer period of time. With the third approach, and even in the case of a complete communication crash, the aircraft would simply continue with the original flight plan and return to the base as originally intended to.

In spite of the project's overall success, some improvement opportunities have been identified. One possible improvement in maneuver definition and execution is the possibility to specify whether the circle and helix movements should be executed banking to the right or to the left. Currently, this is determined by the algorithm as described in section 3.4, resulting in some unpredictability. Another possible improvement would be to automate landing procedures, by automatically selecting the best runway for landing and determining a series of waypoints as to align the aircraft with the runway. Some additional factors that would increase the level of realism of the simulation could be achieved by fault injection, such as the introduction of noise in communication, as well as failures in some aircraft systems, sensors and actuators.

The next step of this project is to select an agent platform as to facilitate communication between agents, to assist in the execution of cooperative missions. When completed, the system will allow for the cooperative planning and execution of missions, such as surveillance of given areas, such as forests – to facilitate early fire detection – or coast lines – to detect and help prevent illegal activities – or even areas affected by pollution, to detect the source and probable progression of the polluting chemicals. The system can also be used to assist in military operations, such as search & rescue operations, covering a larger search area, or enemy surveillance operations.

As a final summary, one can say that the simulation environment shows promising capabilities, namely when referring to structured experiences; the aircraft control approaches were tested successfully, and the future of the project is promising, with many possible useful applications.

REFERENCES

Stone, R. 2005. "Serious Gaming". *Defense Management Journal*, issue 31 (Dec), 142-144.

Danek, G.L. 1993. "*Vertical Motion Simulator Familiarization Guide*". Technical Memorandum 103923. NASA Ames Research Center, Moffett Field, California, USA (May).

National Aeronautics and Space Administration. 2008. "*Vertical Motion Simulator*". NASA Ames Aviation Systems Division (Dec). Available online at http://www.aviationsystemsdivision.arc.nasa.gov/facilities/vms/index.shtml.

Tran, D. and E. Hernandez. 2004. "Use of the Vertical Motion Simulator in Support of the American Airlines Flight 587 Accident Investigation". *American Institute of Aeronautics and Astronautics Modeling and Simulation Technologies Conference and Exhibit* (Aug), Providence, Rhode Island.

Samek, J., D. Sislak, P. Volf and M. Pechoucek. 2007. "Multi-party Collision Avoidance Among Unmanned Aerial Vehicles". *IEEE/WIC/ACM International Conference on Intelligent Agent Technology (IAT'07)*, California, 2-5 November, 403-406.

Zhang, X., R. Xu, C. Kwan, L. Haynes, Y. Yang and M.M. Polycarpou. 2005 "Fault Tolerant Formation Flight Control of UAVs". *International Journal of Vehicle Autonomous Systems*, Vol. 2, Numbers 3-4 (Feb), 217-235.

Schurr, N., J. Marecki, M. Tambe, P. Scerri, N. Kasinadhuni and J.P. Lewis. 2005. "The Future of Disaster Response: Humans Working with Multiagent Teams using DEFACTO". *American Association for Artificial Intelligence (AAAI) Spring Symposium on AI Technologies for Homeland Security*, 2005.

Stark, P. 2007. "FSX Mission Building, Parts 1–4". *PC Pilot Magazine*, Key Publishing Ltd. Issue 48 (Sep), 40-43; 49 (Nov), 40-44; 51 (Jan 2008), 40-44; 52 (Mar 2008), 40-44.

Microsoft Corporation. 2008. "Microsoft ESP – A New Era in Visual Simulation". (Dec) Available online at http://www.microsoft.com/esp/.

Training & Simulation Journal. 2008. "Lockheed Martin, FlightSafety to use Microsoft ESP platform". *Training & Simulation Journal Online* (Feb 21). Available online at http://www.tsjonline.com/story.php?F=3384514.

Erdos, D. and S.E. Watkins. 2008. "UAV Autopilot Integration and Testing" *IEEE Region 5 Conference* (Apr) 94-99.

Skogestad, S. 2003. "Simple Analytic Rules for Model Reduction and PID Controller Tuning". *Journal of Process Control*, Vol. 13, Issue 4 (Jun), 291-309.

CloudCap Technology. 2008. "A Brief History of Piccolo Development" (Jun), Hood River, Oregon, USA.

THE MATHEMATICAL MODELING ON THE HYBRID COMPUTER ARCHITECTURE FOR THE FLIGHT SIMULATOR

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INTRODUCTION

It is possible to solve some tasks of kinematics as well as dynamic affiliated with simulators objects motion. The physical issue of graphics construction of the assembling motion can be replaced by mathematical formulation with depiction continuance of the mathematical function.

Design and creation of such information systems with distributed databases are important assumptions for the decentralized control systems (Blakelock 1991).

To simulate the system of differential equations – mathematical models, it is necessary to change the mathematical form of the object.

MATHEMATICAL MODEL

We can use method of indeterminating coefficients, method of sequential approximation, as well as method of Taylor series.

The mentioned mathematical model tasks rewrite the system general differential equations. Today it is possible to use two different methods. The fist one is analytical solution of the mathematical model (system differential equations) methods of mathematical analyses. In second case the mathematical model is solved by computer technique (Feitelson 1995).

If we have defined differential equation n-th order in expression (Levinštejn 1977):

$$y^{(n)} = f\left(x, y, y', \ldots, y^{(n-1)}\right) \tag{1}$$

The task is to find the function:

$$y = y(x), \tag{2}$$

For numeric solving the differential equation of higher order we employed the method for solving the system of first order differential equation.

$$\begin{aligned} y' &= y_1, \\ y_1' &= y_2, \\ &\ldots \\ y_{n-2}' &= y_{n-1}, \\ y_{n-1}' &= f\left(x, y, y_1, \ldots, y_{n-1}\right). \end{aligned} \tag{3}$$

After these substitutions create the system of differential equations are created. This system is completed by defining differential equation with substituted variables $y_1,\ldots,y_{n-1}$ and the new system modify to the normal form (Levinštejn 1977) .

For solving the system of equations (3) it is possible to use known numeric methods of differential equation of first order.

PARALLEL MATHEMATICAL MODELING

In situations where more than one program is running at the same time, an symmetric multiprocessing (SMP) system will have considerably better performance than the uniprocessor one because different programs can run on different CPUs simultaneously. SMP is a multiprocessor computer architecture where two or more identical processors are connected to a single shared main memory (Duncan et al. 1994).

The simulation of distributed mathematical model can be created using parallel computer architecture.

Sequential way of mathematical model program run is characterized by equations computing in single computer time. Disadvantage of this method is power constraint of the processor that computes the model. In this case, synchronization and single computer modeling time is very important.

The task can be sequent program (1 CPU) or parallel one - Message Passing Interface (MPI) with more parallel processes. The parallel tasks are executed typically by Message Passing Interface (MPI) using mpiexec call on computer nodes (Pota et al. 2005).

Users can use different programming languages that satisfy the requirements on creation of the parallel computing. The advantages are platform independence and reliably execution (Feitelson 1995).

MATHEMATICAL MODEL OF BACKGROUND

Mathematical models used in flight simulator (see e.g. Rolfem 1986) are modified to desired form. The increment attack angle rewrites equation (10), defines from change per supply (11) and increment per position elevator attack angle (12):

$$\Delta\alpha(s) = -W_{\alpha}^{\delta_T}(s)\Delta\delta_T(s) - W_{\alpha}^{\delta_B}(s)\Delta\delta_B(s), \tag{4}$$

$W_{\alpha}^{\delta T}(s)$ – transfer function increment attack angle of aircraft per fuel supply, $W_{\alpha}^{\delta B}(s)$ – transfer function increment attack angle of aircraft per elevator, in system equations (Krasovskij 1980). For fuel supply:

$$W_{\alpha}^{\delta_T}(s)=5\frac{0{,}002s^2-0{,}25s-0{,}1}{s^4+1{,}13s^3+62{,}8s^2+28{,}67s+4{,}1}. \quad (5)$$

For elevator:

$$W_{\alpha}^{\delta_B}(p)=\frac{0{,}11s^3+0{,}32s^2\cdot 1.72s+0.28}{s^4+1{,}13s^3+62{,}8s^2+28{,}67s+4{,}1}. \quad (6)$$

In equation (4) introduces the change of fuel supply on step in Laplace transformation ΔδT (s)=1/s, introduces the change of elevator position on step in Laplace transformation ΔδB (s)=1/s, respectively.

ARCHITECTURE OF FLIGHT SIMULATOR

The most used parallel systems are based on either shared memory, distributed memory or hybrid distributed-shared memory systems. The authors published their experiences with distributed architecture (see Kvasnica et al. 2007 and 2008) where divide the modeling problem among many computing nodes. The presented system combines local memory and the processor at each computing node connected through interconnection network.

Distributed Architecture

Distributed architecture is realized as the connection of five nodes (one is head computer, others are computing nodes). The system combines local memory and the processor at each node connected through interconnection network. Due to the fact that is necessary to move data from one local memory to another by means of message passing. This is done by send/receive pairs of commands. Each node is able to put the receiving data to the buffer. The MPI system includes also the basic tools for parallel running process coordination as is barrier synchronization, precedence synchronization etc. It provides the time synchronization of all nodes after the MPI initialization (MPICH2 2006), (El-Rewini 2005).

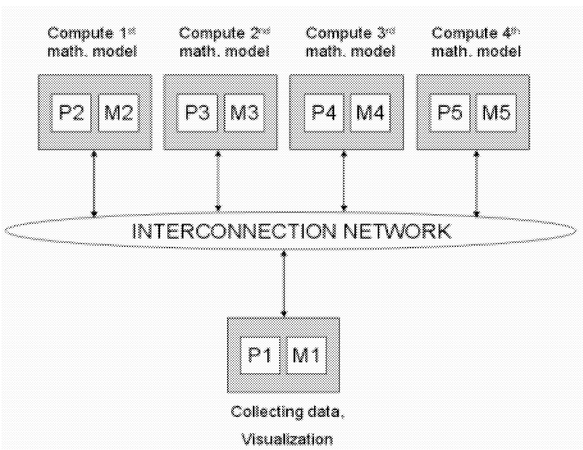

Fig. 1: Design of interconnection architecture of simulator

The software part was considered on the use C++ language as a language for implementing MPI.

Pseudocode of the main application is shown in Figure 2. MPI_Barrier() function in a program caused the node block until this function is not called also from the others nodes (Chapman 2007).

```
MPI_Init()
...
MPI_Barrier()
if (processor == 0){     //central
node
   // collecting data + visualization
} else {
   switch (processor)    //2 computing
nodes
   {
          case 1:
ModellingSystem1(); break;
          case 2:
ModellingSystem2(); break;
   }
}
MPI_Finalize()
```

Fig. 2: Pseudocode of MPI application

The application on head node consists of two layers – application layer coded in C++ that uses also MPI functions and the presentation one coded in C#. The C++ language is used for its good computational speed and .NET Platform (C# language) for its good visualization support.

The software application consists of main console window with information messages about processing and graphical windows with graphs. Application is also coded in C++ language with OpenMP support and the graph component is the same component as is mentioned in previous section.

Shared Memory Architecture

Shared memory computing is based on multicore processors that can issue multiple instructions per cycle from multiple instruction streams. The same simulation problem described above has been also realized on shared memory based on OpenMP standard that supports multi-platform shared-memory parallel programming in C/C++. OpenMP was used due to some advantages comparing with POSIX Threads (OpenMP 2007).

OpenMP parallelism uses the fork-join programming model, where some threads is created by a fork operation and is joined at the end, as shown in Figure 3.

The main function split the problem processing using parallel region construction directive ("omp parallel"). The thread computes different equation and visualizes the results of modeling in real-time in the form of dynamic graph.

Programmatically, OpenMP is based on compiler directives imbedded in source code which make a simple way to maintain a single code for the sequential and parallel version of the application due to the existence of conditional compilation. The parallelism used in OpenMP is explicit - the user specifies the regions in the source code that are parallel.

Multiple threads within the same process can be assigned to different processor or core. Typically, a number of created threads are equal to the number of available processors or cores. Threads running simultaneously on multiple processors or cores may work concurrently to execute a parallel program.

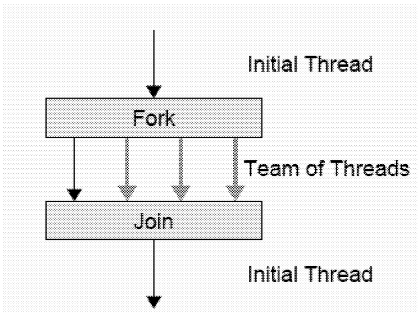

Fig. 3 OpenMP: Fork-Join programming model

Simulation Results

Finally, we can say that from the modeling that uses MPI these points implicit:

- the values integration on decomposed subsystems is necessary to modified according to simulator time (barrier communication)
- decomposition effect of computational system is influenced by synchronization through the network
- the accuracy of the computation is faster than on the one processor system.

Each mathematical model from Section 4 was processed and visualized on separated core.

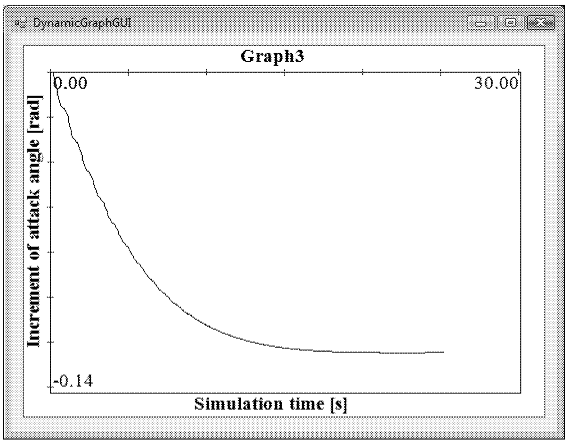

Fig. 4 Graphics results of simulation based on Eqs.(4)

The results are depicted in Figure 4. The simulation time of mathematical models of flight simulator is delimited to 25 seconds for sample and integration step is 5 milliseconds.

CONCLUSIONS

The simulation was realized on different architectures that supports parallel computing so their main advantages. Mentioned method can be applied also in other modeling configuration of flight simulator (Rolfem 1986).

It was used two 4-cores processor's architecture of the node with MPI and with programming equipment support under Windows operating system. Solving the mathematical models using MPI seems to be effective and pragmatic. From the results obtained by cluster simulation we can claim that the subsystem modeling is more difficult but also faster.

REFERENCES

Blakelock, John H.: *Automatic control of aircraft and Missiles*, Second Edition, John Wiley & Sons. Inc.: New York, 1991, ISBN 0-471-50651-6.

Duncan, S. H., Gordon, P. L., Zaluska, E. J. and Edwards, S. I. : *Parallel processing in high integrity aircraft engine control*, Springer Berlin, 1994, ISBN 978-3-540-57980-9.

El-Rewini, H., Abd-El-Barr, M.: Advanced Computer Architecture and Parallel Processing, John Wiley & Sons, Inc.: New York, 2005, ISBN 0-471-46740-5.

Feitelson, D., G., Rudolf, L., “Parallel Job Scheduling: Issues and Approaches“ Lecture Notes in *Computer Science*, Vol. 949, p. 11-19, 1995.

Chapman, B., Jost, G., van der Pas, R., Using OpenMP - Portable Shared Memory Parallel Programming. The MIT Press: Massachusetts, 2007, ISBN 978-0-262-53302-7.

Krasovskij, A., A.: *Sistemy avtomaticeskogo upravlenja poletom i ich analiticeskoje konstruirovanie*. Nauka, Moskva 1980, pp. 589.

Kvasnica, P., Páleník, T., Čižmár, M. Mathematical Model of Aircraft and its Visualization Using MPI. In *3rd International Workshop on Grid Computing for Complex Problems*, GCCP 2007 Proceedings, Bratislava: Slovak Academy of Sciences, 2007. pp. 117-125. ISBN 978-80-969202-7-3.

Kvasnica, P., Páleník, T. Multicore Processor Architecture for Flight Simulator Modeling. In *4rd International Workshop on Grid Computing for Complex Problems*, GCCP 2008 Proceedings, Bratislava: Slovak Academy of Sciences, 2008. pp. 46-53. ISBN 978-80-969202-9-7.

Levinštejn, *Operátorový počet v elektrotechnike*, SNTL Praha, 1977, pp.14-15.

MPICH2 is a high performance and widely portable implementation of the Message Passing Interface (MPI) standard, www.mcs.anl.gov/mpi/mpich2.

Pota, S., Sipos, G., Juhasz, Z., Kacsuk, P., Distributed and Parallel Systems, Parallel Program Execution Support in the JGRID System, Springer Science, New York 2005, ISBN 0-387-23094-7, p. 13-19.

Rolfem J.M., Staples, K.J.: *Flight Simulation*, Cambridge University Press : Cambridge, 1986, ISBN 0-521-35751-9.

BIBLIOGRAPHY

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RISK MANAGEMENT AND ASSESSMENT SIMULATION

DIGITAL TECHNOLOGIES FOR FOREST FIRE SUPPRESSION: AN APPLIED STEP IN MEANS MANAGEMENT

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KEYWORDS
Crisis management, forest fires, decision support, means dispatching, tactical situation.

ABSTRACT

In order to coordinate the fight against forest fires, software tools based on geographic information systems are used more and more. This paper deals with an example of the coordination of forest fire fighting activities from mobile command posts. Thus, we specify the respective duties of the fire-fighters who play a central role in the chain of command. The corresponding tasks are carried out with the help of Asphodèle, a software system which has been developed for the management of human and material resources involved in forest fire suppression. The description of the different interactions between the fire-fighters concerned is made by means of UML sequence diagrams. We conclude on the fact that a significant gap remains between academic contributions and forest fire suppression managers.

INTRODUCTION

Forest fires are among the worst natural catastrophes. Each year, between six hundred thousand and one million hectares are consumed by flames in the European Union. Furthermore, this curse often induces severe ecological and social damage. For instance, the modification of ecosystems may result in the extinction of animal and plant species. Moreover, inhabited zones are often threatened, especially in the Mediterranean basin. Therefore, considerable means are currently devoted to fire-fighting activities: these may involve up to several thousand firemen supported by vehicles and aircraft. Forest fire suppression is thus becoming a crucial challenge today, both for local populations and firemen.

RESEARCH WORKS ON FOREST FIRES

Research works related to forest fires are extremely varied. They range from the study of the physical and chemical properties of the different kinds of wildland fuel to the implementation of dedicated software tools, e.g. decision support systems (DSS). In this context, digital technologies address several key issues in forest fire suppression management. Although they are mutually related, at least four different application fields can be identified.

Risk evaluation

Fire risk evaluation turns out to be especially useful for all the tasks which must be carried out prior to a fire occurring, e.g. means pre-positioning. Therefore, various danger rating systems have been developed all around the world. The corresponding risk indices (Burgan 1994), (Sebastian-Lopez et al. 2001) are calculated as a function of weather variables, e.g. temperature, air, soil and fuel moisture content, wind intensity etc. as well as permanent data, e.g. topography, vegetation types, urbanization, etc.

Fire detection

Fire ignition in forest massifs must be detected as soon as possible in order to allow early action. Moreover, throughout the fighting of the fire, the successive perimeter(s) of the fire must be accurately identified. The corresponding tasks can be carried out automatically (Chuvieco 2006) by means of sensors dispatched in the forest, infra-red cameras positioned on observation towers, or even through satellite supervision. Nevertheless, for economic reasons, this activity is generally effected by human observers dispatched on the ground or aboard helicopters.

Fire behaviour simulation

Forest fire simulation is a highly challenging scientific domain and consequently it has been a very active field of research for many years. Thus, since Rothermel's work (Rothermel 1972), many systems based on empirical or semi-empirical approaches have been implemented in North America, e.g. (FCFDG 1992), (Finney 1998), (Rabner et al. 2001), and in Europe, e.g. (Vasconcelos and Guertin 1992), (Caballero et al. 1994; 1999), (Lopes et al. 2002), (Vakalis et al. 2004). However, due to the extreme complexity of the problem, significant progress must be made before extensive use can be envisaged.

Means dispatching

Management of fire suppression requires the action of terrestrial means, as well as that of aircraft. Together, these ones implement a strategy defined by the officers who are at the head of the intervention. Beyond the difference of scale, we are here close to the field of military tactics.

Furthermore, it is worth noting that few software systems (Intergraph 2006) are specifically designed for forest fire suppression. In fact, most of them are commercial products distributed by geographic information systems editors. They are generic tools intended for civil protection intervention management and are more or less customized for forest fire suppression.

Of course, the activities referenced above, i.e. risk assessment, fire detection and fire simulation, are strongly related to means dispatching. In this setting, the corresponding DSS tools, which are generally developed in cooperation with academic partners, may be extremely useful. For instance, projected fire-fighters activities can very well be taken into account by simulations. Recommendations about the fire suppression strategy to be implemented can also be provided according to automated reasonings (Caballero et al. 2001). Nevertheless, means dispatching remains a highly sensitive matter. Obviously, because of the risks incurred by fire-fighters, this activity cannot be fully automatized. Thus, we argue that in terms of means management, digital technologies should be confined to support and assistance. Hence, we deal in this paper with a business process oriented software system called *Asphodèle* (Dumond 2006) which aims to faithfully reflect the French doctrine in terms of forest fire suppression management. Therefore, the required skills for operation are those which are specific to any officer usually involved in such interventions.

FOREST FIRE SUPPRESSION MANAGEMENT

Forest fire suppression is a very complex activity which implies numerous different tasks. Among these, we can cite:

1. A careful analysis of the operating zones from the point of view of their natural characteristics, e.g. vegetation and relief. Furthermore, the presence of any kind of man-made structure, e.g. access roads, houses, forest tracks, high voltage lines, etc. is considered as well. In this setting, special care is devoted to critical points such as hospitals, leisure parks or sensitive industrial infrastructures.
2. A rigorous locating of fire hydrants and of water tanks. The latter are dispatched in the forest and filled beforehand.
3. A periodic collection of all information regarding the fire: this in particular concerns the perimeter of the burning areas and the identification of the different spreading axes.
4. The management, according to the different objectives related to the implemented strategy, of all the material and human means deployed on the ground.
5. A prospective step that aims at predicting fire growth in the short term, i.e. within a period of a few hours, as a function of the various available data, in particular the geographic characteristics of the operating zones and the weather forecast.
6. A permanent interaction with the staff headquarters, which provides additional means whenever they are needed. Communication with the administrative authorities has to be handled, too.

Management from mobile command posts

In France, the staff headquarters of a fire brigade is mostly in charge of the coordination of numerous concurrent interventions: this in particular implies the distribution of the available means. Therefore, forest fire-fighting activities are managed from mobile command posts, i.e. trucks dedicated to this mission. All the data related to the situation on the ground is periodically sent to the staff headquarters for an accurate evaluation.

The command posts, which are generally two in number, are parked close to the fire areas and radio antennae are erected in order to allow communication with the units deployed in the field. Whenever possible, the command posts are also connected to the telephone network: this facilitates Internet communication with the staff headquarters and the forecast service. The two command posts carry out different and complementary missions. Hence, we have to distinguish the *intervention management unit* from the *anticipation unit*, the respective functions of which are detailed below. In addition, a lighter structure, the *air support unit* aims at coordinating the aerial means involved in the intervention. This requires a permanent contact with the intervention management unit.

The intervention management unit

The intervention management unit is dedicated to the organization of the fighting activities in the strict sense of the word. For that purpose, it is equipped with several laptops connected to additional 19-inch flat screens. In addition, it has radio communication: in this way, orders are transferred to the fire-fighters, who in turn keep the command posts informed of the development of the situation. The following is the personnel working in an intervention management unit:

1. A commanding officer who is at the head of the intervention.
2. An operator for the communication (Radio, UMTS, Internet) with the staff headquarters.
3. An officer (the *"tactical situation manager"*) in charge of the management, i.e. elaboration and successive updates of the tactical situations. This officer is in permanent contact with the units deployed in the field.
4. An officer (the *"mobile means manager"*) in charge of the management of the means deployed on the ground. As with the previous one, this officer is in permanent contact with the fighting units.

The anticipation unit

The *anticipation unit* is the support for all the prospective activities. These tasks are directly related to fire growth prediction and are regarded as a key issue in the management of the operations. For that reason, they are entrusted to two experienced officers who make use of their skills and knowledge. Being freed from the constraints of the management of the intervention, the latter can make objective analyses of the situation. Thence, they are in a position to suggest specific steps such as requesting new means, suggesting new potential strategies or paying attention to the protection of critical points, e.g. planning the evacuation of populations.

In this framework, fire growth estimation is carried out through a detailed study of the areas concerned: this task is made easier by 3-D displays and aerial photographs. The results obtained by means of these informal reasonings are then compared to those provided by numerical simulation.

The air support unit

The *air support unit* is in charge of the coordination of the actions performed by aircraft, i.e. planes and helicopters. Roughly speaking, this activity can be compared to air traffic control. Hence, the officer responsible for this task has to help aircraft to drop water and retardant, as precisely as possible, on the areas specified by the command in order to extinguish, stop or slow down the fire.

FIRE FIGHT MANAGEMENT WITH ASPHODELE

Tactical situation management

The elaboration of *tactical situations* consists in adding dedicated graphical items to background maps, i.e. different kinds of geological survey maps and aerial photographs. This concept is well-known in military settings. It is especially well suited when the chain of command has to cope with the problems related to the coordination of a huge number of means.

In the present setting, the graphical items in question abide by a national standard that specifies their form and their semantics. Furthermore, they illustrate four kinds of notion:

1. The attributes of the fire, e.g.: starting point(s), burning area perimeter, main and secondary spreading axes, etc.
2. Fixed means, e.g.: water hydrants, hospitals, oil storage, parking areas, etc.
3. Mobile means, e.g.: command posts, group columns, oil supply vehicles, medical and veterinary units, psychological support, etc.
4. The different actions performed by the fighting-units, e.g.: support lines, flank attacks, water dropping, etc.

These different items can be divided into two sets:

1. About thirty different icons that can be laid down, as they are, onto different kinds of background map.
2. About twenty different kinds of linear structure which are drawn by means of the mouse pointer.

Once a tactical situation has been completed with the help of a specific editor which is part and parcel of the Asphodèle system, it offers a synthetic and unambiguous view of the situation on the ground (cp. Figure 1) which can either be displayed in 2-D or in 3-D.

To some extent, a tactical situation may be regarded as a formal specification dealing with the topography of the operating zone, the characteristics of the fire and the implemented strategy. Note that during the interventions, tactical situations are periodically recorded in order to allow *a posteriori* analyses.

Figure 1: Example of a tactical situation edited with the Asphodèle system © SDIS 06.

Mobile means management

Mobile means management has to be apprehended through two main concepts, namely the *life cycle* of mobile means and the division of the operating zones into *sectors*. Thus, a mobile means is successively:

1. *Required* on behalf of the commander.
2. *Obtained*, i.e. allocated by the staff headquarters.
3. *Available*, after a given time, at a precise location called a *transit point*.
4. *Engaged* in one of the geographical sectors (see below).
5. *Released* after a sufficient duration of engagement.

Moreover, any operating zone is divided into three different *geographical* sectors:

1. the *head forward boundary* which corresponds to the main flame front.
2. the *right side boundary*.
3. the *left side boundary*.

On the ground, an officer is at the head of each of these sectors. He is the main interlocutor for the intervention management unit personnel for all the questions regarding the sector he is in charge of. In addition, a dedicated sector gathers all the means dedicated to command and support activities, e.g. the command posts, the medical and logistics support, the air support unit and the aerial means, etc. This sector must be considered from a functional point of view rather than a geographical one, even though the corresponding means, apart from the aerial means, are precisely located on the tactical situation.

A specific module of Asphodèle provides an overall view of all the mobile resources devoted to the intervention. Broadly speaking, the interface of this module has the appearance of a dedicated spreadsheet (cp. Figure 2) in which columns denote the successive steps of the aforementioned life cycle as well as the different sectors. Throughout the intervention, in order to faithfully reflect the situation on the ground, the icons representing the mobile means are consequently moved from one column to another one by a *drag and drop* procedure. Furthermore, some additional information, e.g. the duration of engagement, the availability of specialized equipment, etc. can be accessed by a simple mouse click on the suitable icon. This data allows optimal management of the different means.

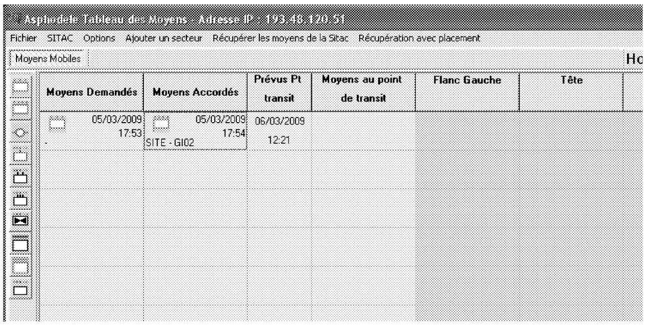
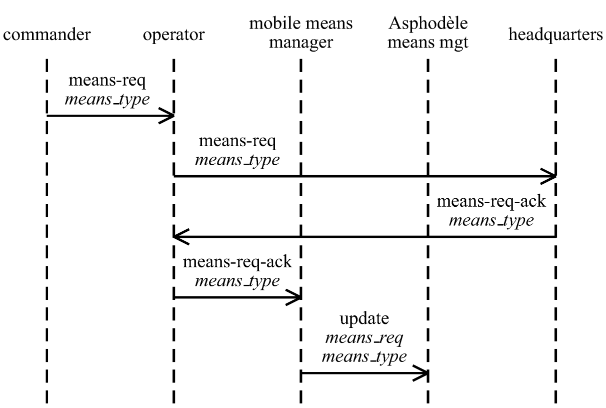


Figure 2: Interface of the mobile means management module © SDIS 06.

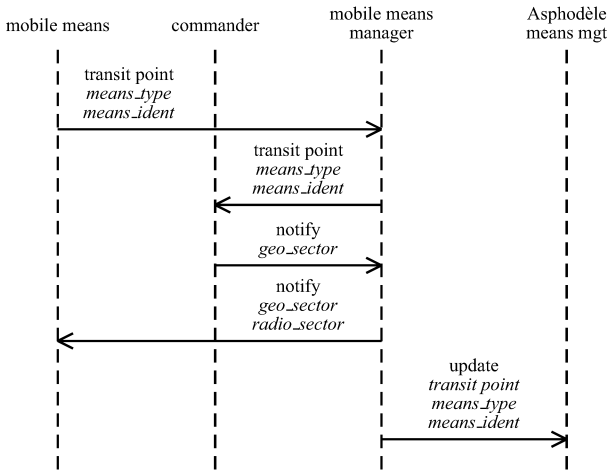
COOPERATION INSIDE A COMMAND POST

The following are UML sequence diagrams that specify some examples of interaction protocol between the firemen working in the intervention management unit and their environment: headquarters, air support unit, fire-fighter units deployed on the ground, etc.

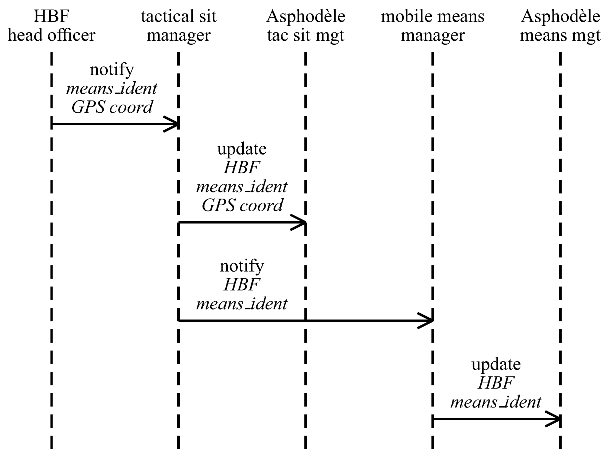
1. The commander asks the headquarters, through the operator, for an additional means of the kind $means\_type$. Then the headquarters acknowledges the means requirement and the operator informs the mobile means manager. The latter updates the corresponding data in the mobile means management module.



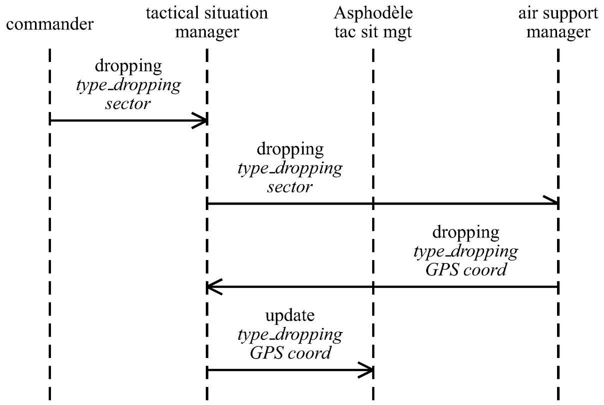
2. A new mobile means informs the mobile means manager that it has reached the transit point. The commander notifies to it, through the mobile means manager, the geographical sector it will be engaged in. The radio channel of the sector's leader is provided too. Then, the corresponding data is updated in Asphodèle.



3. A mobile means coming from the transit point or another sector has actually been engaged in the head forward boundary sector. The officer who is at the head of the latter informs the tactical situation manager of the precise location of the means in question, i.e. the GPS coordinates. The tactical situation is updated in Asphodèle and the mobile means manager is informed. The latter in turn updates the corresponding data in Asphodèle.



4. The commander requires a dropping of a given type (water or retardant) in a given geographical sector. The choice of the location of the dropping inside the specified sector is the responsibility of the air support manager. While he waits for the answer, the tactical situation manager attends to other tasks: this is modelled by an asynchronous message in the sequence diagram. When the dropping has been performed, its precise location, i.e. the GPS coordinates, are sent to the tactical situation manager who updates the corresponding data in Asphodèle.



CONCLUSION

The recourse to digital technologies, such as integrated software systems, in forest fire suppression management actually reflects current and future trends. In the long term, this will indisputably increase the efficiency of fighting activities. However, their large-scale use faces the following problems:

1. Budgetary constraints, since these technologies are highly expensive, in particular in their most sophisticated forms, e.g. remote sensing.
2. Many techniques related to forest fires, such as fire behaviour simulation, are clearly not mature. Therefore, they cannot be regarded as reliable enough for human safety to depend on them.
3. The knowledge of the end-users, in terms of IT technology, is generally not good enough to allow an optimal use of highly sophisticated tools. Hence, filling the gap between academic research and fire-fighters working on the ground appears as a major challenge for the future.

REFERENCES

Burgan R., 1994. *A preliminary look at next generation fire danger rating technology*. In *Proceedings of 1994 Interior West Fire Council Meeting and Program, Fairfield, WA, USA*.

Caballero D.; Martinez-Millan F.; Martos J.; and Vignote S., 1994. *Cardin 3.0, A model for forest fire spread and fire fighting simulation*. In *Proceedings of the 2nd International Conference on Forest Fire Research, 21-24 November, Coimbra, Portugal*.

Caballero D.; Viegas D.; and Xanthopoulos G., 2001. *E-FIS: an electronic on-line decision support system for forest fires*. In *Proceedings of the International Workshop on improving dispatching for forest fire control, 6-8 December, Creete, Greece*.

Caballero D.; Xanthopoulos G.; Kallidromitrou D.; Lyrintzis G.; Bonazountas M.; Papachristou P.; and Pacios O., 1999. *FOMFIS: Forest Fire Management and Fire Prevention System*. In *Proceedings of DELFI International symposium on Forest Fires Needs and Innovations, 21-24 November, Coimbra, Portugal*.

Chuvieco E., 2006. *Remote sensing of forest fires – Current limitations and future prospects*. Advances in global change research. Observing land from space: science, customers and technology. Kluwer Academics Publishers.

Dumond Y., 2006. *Modelling the fight against forest fires by means of a numerical battlefield*. In *Proceedings of the 20th European Simulation and Modelling Conference, October 23-25, Toulouse, France*.

FCFDG, 1992. *Forestry Canada Fire Danger Group: Development and structure of the canadian forest fire behaviour prediction system, Information report ST-X-3*. Ottawa, Canada.

Finney M., 1998. *FARSITE: fire area simulator-based development and evaluation, Rocky Mountain Research Station, research paper 4, Ogden, UT*. US Department of Agriculture, Forest Service.

Intergraph, 2006. *FireTactic ® user's manual, version 7.9*.

Lopes A.; Cruz M.; and Viegas D., 2002. *Firestation – an integrated software system for the numerical simulation of fire spread on complex topography*. Environmental Modelling & Software, no.17, pp.269–285.

Rabner K.; Dwyer J.; and Cutter B., 2001. *Fuel model selection for BEHAVE in midwertern oak savannas*. Northern Journal of Applied Forestry, vol.18, no.3, pp.74–80.

Rothermel R., 1972. *A mathematical model for predicting fire spread in wildland fuel*. Intermonutain Forest and Range Experiment station, General Technical Report INT-115, Ogden, UT: USDA, Forest Service.

Sebastian-Lopez A.; Salvador R.; and San-Miguel-Ayanz J., 2001. *Two models for a structural forest fire risk at a regional scale*. In *Proceedings of the 21st EARSEL Wokshop on Remote sensing and GIS applications to forest fire management: new methods and sensors, 14–17 May, Paris, France*.

Vakalis D.; Sarimveis H.; Kiranoudis C.; Alexandridis A.; and Bafas G., 2004. *A GIS based operational system for wildland fire crisis management I. Mathematical modelling and simulation, II. System architecture and case studies*. Applied Mathematical Modelling, vol.28, issue 4, pp.389–410 & 411–425.

Vasconcelos M. and Guertin D., 1992. *FIREMAP – simulation of fire growth with a geographic information system*. International Journal of Wildland Fire, vol.2, pp.87–96.

BIOGRAPHY

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A WEB DECISION SUPPORT SYSTEM FOR GAS PIPELINE RISK ASSESSMENT

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KEYWORDS
Risk analysis, Gas Pipeline Risk Management, Indexing Methods, and Web Based Decision Support Systems

ABSTRACT

The assessment of the risk is a key factor in every Pipeline Integrity Management System (PIMS). In order to maintain gas pipeline integrity we must understand the risk factor. This includes the analysis of the probability of failure and the potential consequences. There are two approaches to estimate the risk: quantitative and qualitative. The quantitative methods involve historical failures date base or computer simulation. The qualitative methods are based on the expert's opinions and can gather the local experiences of the pipeline operator. In this paper the model based on the qualitative risk indexing method is presented. Two groups of gas pipelines and surroundings parameters are considered. In the first group are parameters which have the influence on the probability of failure. The second group is constituted from the parameters which have influence on the potential consequences.

Having the list of these parameters the relative importance of each parameter is discussed among the group of experts. Once the consensus is reached, the model of pipeline failure risk estimation is created. In the next step the risk categories criteria are formulated. The risk criteria for five risk categories were formulated.

The model and the risk categories were implemented in the Web based decision support system. The pilot tests of the system were performed and the results are presented.

INTRODUCTION

Gas pipelines are recognized as the safest mode of transportation. However, sometimes they do fail, often with severe consequences. Therefore, there is a risk of pipeline failure which cannot be totally eliminated.

In order to manage the pipeline risk Operators need to identify and estimate it. They would like to know what the risk of pipeline failure is.

Risk R is defined as the product of two variables P and Q:

$$R = P \cdot Q \qquad (1)$$

Where P is the probability of failure and Q is the consequence if the risk is materialized.

There are two approaches to risk analysis. One is qualitative and the other is quantitative. In the first one the risk level is characterized without quantifying it. In the second approach the risk level is calculated on quantified estimates of failure probability and consequences probability. Quantitative approach is more sophisticated and detailed. It involves the incident data base to perform statistical calculation or uses physical models to estimate risk by analytical methods. The qualitative approach is simple and relative. One of the qualitative methods is indexing (Muhlbauer 1996). In this paper the qualitative risk indexing method is presented.

THE MODEL

The model is designed to help pipeline operators identify, analyze and mitigate the risk of pipeline failures.

The model construction was done in two stages. In the first stage the parameters which have an impact on the probability of pipeline failure were chosen. The causes of failure as well as their occurrence frequency were analyzed. These parameters contain information and data from five thematic groups:

- Quality systems applied
- Physical characteristics of the gas pipeline
- Operational and organizational factors
- Technical condition of the gas pipeline
- Corrosion control

In the second stage the parameters which have impact on the potential consequences of failure were chosen. The potential consequences of failure depend on the localization of the pipeline, population density in vicinity of the pipeline, crossings and interferences. The applied mitigation methods of pipeline failure consequences were taken into consideration. There are 22 parameters analyzed in the first stage and 11 in the second stage. Then the adequate weights were assigned to each parameter throughout the expert's judgment. The relationships among the chosen parameters were analyzed and taken into account in the weighting process. The point system was created and accepted by all parties involved in model construction. The consensus was reached.

THE RISK CATEGORIES

Risk categories are defined by the number's intervals. Each analyzed segment of gas pipeline is characterized by the relative Total Risk Index (TRI). The value of TRI will decide in which risk category the considered pipeline segment falls. Moreover, for each risk category some recommendations are suggested (see Table 1).

Table 1: Risk categories and recommendations

Risk	Recommendations
Very high	Immediate replacement or withdrawal from operation
High	Necessarily included in the repair & modernization plan
Moderate	Additional diagnostics as well as modernization or repair possibility consideration
Small	Standard operational monitoring as well as additional inspection of the chosen segments of pipeline
Very small	Standard operational monitoring

In a way, risk categories criteria define the operator's safety policy. Safety is strictly connected with the cost. There is no possibility to eliminate risk completely. There is a risk level which can be acceptable. Risk level which cannot be tolerated must be reduced or transferred to others, e.g. insurance company. The next step was an implementation of the model and risk criteria into computer system which could serve gas pipeline Operator as a computer tool.

Pipeline Operators need to have in place an easy understandable computer tool which helps them to make rational decisions in operating and maintaining pipelines. Therefore, the model and risk acceptance criteria were implemented in the Web based support system called **SOREG**®(**S**ystem **O**ceny **R**yzyka **E**ksploatacyjnego **G**azociągu).

COMPUTER SYSTEM

The SOREG was designed as Web based decision support system. The PHP language, Java scripts as well as MySQL Data Base were used to create the SOREG (Welling L. and Thomson L. 2005). There are two kinds of users of the system. The first one is an Administrator and the second is Operator. There is only one Administrator. There could be more than one Operator. They both work with the system throughout their own panels. The Administrator has a power over the model and the risk categories and also creates the Operators in the system. It means that Administrator has the possibility of changing the model and can set up the new risk categories. The Operators logins and the passwords are assigned by Administrator. There are two kinds of Operators. One is called Active Operator (AO) who can define the gas pipeline, do evaluation, print the reports and also review and edit the results. The second one is called Passive Operator (PO) who may only review the results. However PO does not have rights to edit them and cannot define a new gas pipeline in the system. PO does not have authorization to make his own evaluation of the gas pipeline.

There are two modes of working with the system. One mode is referring to the managing of the gas pipelines and the other deals with the managing of the evaluations. All pipeline evaluation results are stored in the data base.

Work with the SOREG system involves the following four steps:

1. In the first step the object of the evaluation must be defined. It means that the gas pipeline, if necessary is breaking into segments. The amount of segments and their size depend upon the parameter changes.
2. Input the values of each parameter by typing them or importing from the others` data bases.
3. The system carries out the risk assessment for the pipeline segment being analyzed.
4. Automatically two kinds of reports (tabular and graphical) are created, which can be saved, printed or displayed.

As a result, each segment of gas pipeline is characterized, in terms of posed risk by the relative Total Risk Index. The general idea of the SOREG system is presented in Figure 1.

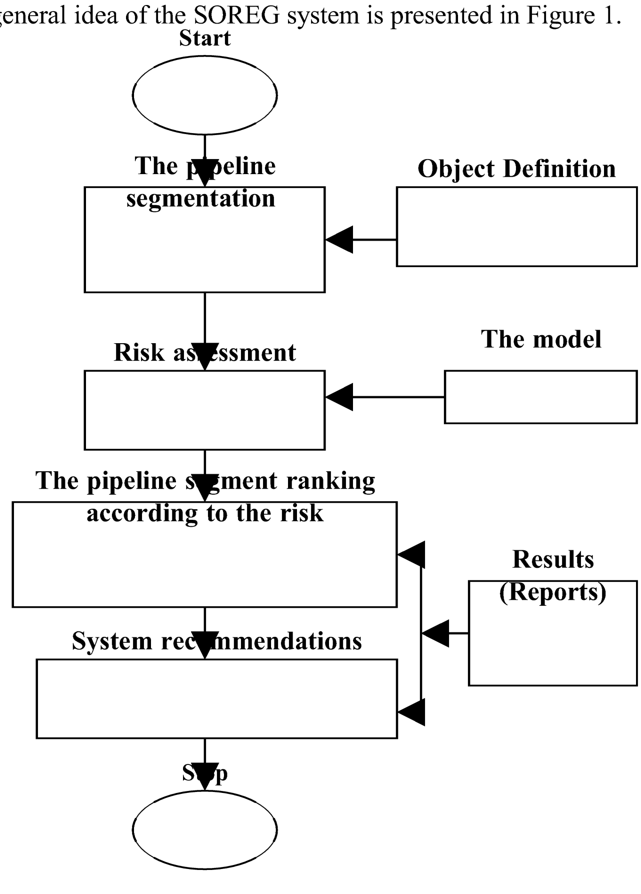

Figure 1. The general idea of the SOREG system

Additionally, if necessary, there is an option to carry out "what if" analysis. By changing the value of one or more parameters one can create the new scenario which will show the influence of the change in parameters on the results.

THE PILOT TESTS

The pilot tests were conducted by three Polish gas pipeline Operators. The gas pipelines being evaluated were chosen carefully trying to cover many different situations. The technical condition of the gas pipelines being analyzed was known very well to the Operators. In most of the cases the results obtained from the SOREG confirmed the knowledge of the Operators about the analyzed gas pipelines.

Some small changes were made in descriptions of the parameters, assigned points and definition of risk categories. They were also some remarks concerning the functionalities of the system.

The pilot tests of SOREG system on 19-th real gas pipelines are promising and showed that such approach can help operators to prioritize which pipeline segment should be first repaired or needs inspection or additional diagnostics. There is also economical aspect of such approach, because the funds will be spent on these pipelines which really need it and are the potential source of hazard.

FUTURE WORK

In spite of promising results of SOREG system pilot tests more work is needed. The schedule of new future tests on real gas pipelines is elaborated. This system will be integrated with other information systems working at Operator site, e.g. GIS.

When the system is implemented then the "good practices" of the specific Operator can be incorporated into the system.

The system can also be easily modified when knowledge and experience are expanded.

CONCLUSIONS

The risk assessment need not necessarily be a complicated process.

This paper presents the easy use approach to cope with pipeline risk management. The risk involved in operation of gas pipelines can be estimated and when known, it can be manageable. The presented point model and its SOREG software implementation can help gas pipeline operators to make the rational decisions in their work. The gas pipeline in operation can be prioritized according to the Total Risk Index. This ranking list can be used in the elaboration process of repair and modernization plans. It can save money. The funds coming from always limited budget will be spent on these segments of the gas pipeline which need it more than others. By using this system the Operator can compare two segments of the gas pipeline based on the same criteria and on the common method.

The system integrates and analyses data coming from different sources. Operator can identify the potential risk and if necessary, can take actions which prevent the pipeline failure. Having such tool in place, the operator can be active in managing the risk. In decision making process the results obtained from SOREG will be integrated with other sources of information. By creating the different scenarios and simulating some action (i.e. repair of the deteriorated coating), gas pipeline Operator can easily see the result of his action on the risk.

With this system, high-consequence areas (HCA) can be identified. Then remediation and mitigation actions can be chosen and taken.

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REFERENCES

Muhlbauer W. Kent. 1996. *"Pipeline Risk Management Manual"* Gulf Publishing Company. Second Edition.

Welling L. and Thomson L. 2005. *PHP and MySQL Web Development.* Polish language edition published by Helion.

BIOGRAPHY

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VERIFICATION AND OPTIMIZATION TOOLS

PROCESS BASED MANAGEMENT OF SPECIFIC GRID CONFIGURATIONS: VERIFICATION OF CHANGES

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KEYWORDS
Information systems, computer networks, verification.

ABSTRACT

Increasing complexity of distributed information systems has led to development of IT management libraries and, specifically, to IT Infrastructure Library (ITIL), that can be considered as a process-based methodology of management automation. The aim of this paper is to outline an approach for verification of changes when tuning IT and, specifically, ITIL management concepts to computing grids. A verification method is developed to justify changes within the framework of tuning. Several examples illustrating the approach are adduced.

INTRODUCTION

In recent years, companies in most industries have become essentially dependent on information technologies (IT) when providing business services to their customers and end users (Paul 2007).

As the underlying IT infrastructure has increased in complexity, it becomes increasingly critical to efficiently coordinate the work done by the different parts of the service management organization (e.g., the server team, network team, storage team, and application teams) in building, deploying, and operating the IT-enabled business services (Paul 2007, Johnson et al. 2007).

Without proper definition of the coordination in a form of processes and their interaction, similarly to widely used model of business processes (Black et al. 2007) expensive service outages can occur due to erroneous changes made to the IT infrastructure that supports mentioned business services.

In determining the desired set of IT management processes (the to-be view), one can either develop from scratch or take advantage of published best practices (Keel et al. 2007).

In the IT-enabled service management domain, a set of industry best practices has been documented in the form of the ITIL Library (IT Infrastructure Library). Generally, IT process management life-cycle consists of three steps as shown in Figure 1 (Paul 2007).

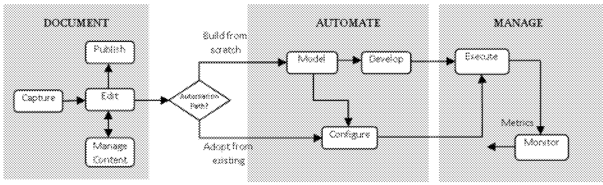

Figure 1: IT Process Management Life-Cycle

Meantime, IT management processes undergo changes during all steps of the life-cycle. IT processes are created to support IT services, which in turn, support business services. Business objectives and therefore business services are changing over time which in turn causes changes in IT processes. These kinds of changes are done at the document step. Automation step can also cause process modifications due to implementation specific issues. At the manage step, analysis of collected metrics can cause modifications in the current process for the process optimization purposes.

Thus, best practice process libraries are, in essence, a set of process templates, which are used to create a specific library of processes aligned to requirements of a given organization. Therefore, after the modification alignment of a given process template it becomes necessary to verify if the newly created process preserves basic properties and, specifically, its functional behavior or, in other words, its functional correctness. Having a library of correct process templates and effective methods of verification, for checking of the each template modification correctness, IT executives can easily create their specific library of (correct) processes, suitable to the specific requirements of their organization. Figure 2 illustrates the role of verification in the IT process management life-cycle.

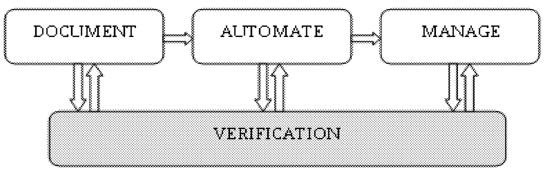

Figure 2: Verification in IT Process Management life-cycle

Grid technologies (Grid computing) have become a commodity of the computer based advanced scientific research via effective harnessing of computing and available data resources and making them seamlessly accessible as a single resource for any user of the grid. For achieving performance and availability objectives a management of grid infrastructure requires specific modifications in ITIL processes.

Per our knowledge there are no tools and methodologies for the verification of IT management processes.

Process functional verification is intended to check the correctness of functions/behavior of the process (Wynn et al. 2008). Functional verification can be done either formally or via process simulation. Presented approach for functional verification combines application of both formal methods and simulation. The suggested approach of verification is applied to a specific networking structure - computing grid (Armenian Cluster) for illustrating the effectiveness of the approach. Preliminary results of experiments are adduced in the paper.

AN APPROACH FOR FUNCTIONAL VERIFICATION OF IT MANAGEMENT PROCESSES

Currently, the most approaches to validate workflow systems have restrictions on workflow control structures that reduce the verification complexity. An idea of modeling workflows by Petri nets gives polynomial complexity for the verification of certain soundness properties a well structured or free-choice control flow (Van der Aalst et al. 2000, Wynn et al. 2008). There were many results in the area of workflow graph structural verification, such as the lack of synchronization, presence of deadlocks and cycles without exit. Most of results have used verification methods based on calculus (Xu and Yu 2007), graph search techniques (Perumal and Mahanti 2007a), model checking (Pfeiffer et al. 2004) and propositional logic (Bi and Zhao 2004). However, the main interest was in general control structure properties, while the semantics of each specific task was not considered. No researches have been done by now on the verification to cover every aspect of workflow systems.

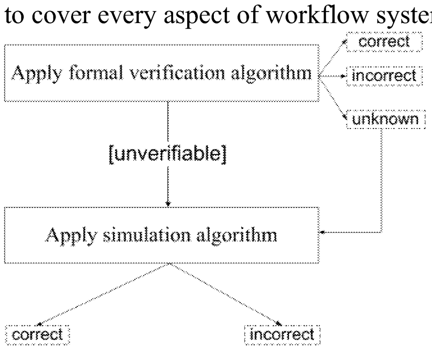

Figure 3: Flow of the IT Management Process Functional Verification Approach

In this paper a method of functional verification of IT management processes is suggested. The Figure 3 illustrates the general schema of the approach.

As a formal model of defining IT management processes is based on the model of IBM's MQSeries Workflow (Leymann and Roller 2000). The IBM's MQSeries Workflow model is extended in two directions. The first one adds necessary formalism for the consideration of formal verification problem. The next one extends process semantics to describe the process simulation algorithm.

Model Definition

The main model components are ***activities*** and ***connectors***. The activities are associated with a context being defined as data passing to an activity. It is called ***input container***. An activity also returns data called ***output container***. Some output container elements of an activity can be passed to the input container elements of other activities or to the ***external memory***. All data elements are collected in the set **V.** Control and data connectors provide connections between the activities. A control connector has an associated Boolean predicate called ***transition condition***. A directed graph based on sets of activities and control connectors is called ***control flow*** of a workflow/business process.

Below comes a short description of the model. Full details can be found in (Leymann and Roller 2000, Kostanyan et al. 2009). The following formal definition of W-processes and cyclic business processes is given by using the designations below:

- If $\mathbf{x}=<\mathbf{x_1},\ldots,\mathbf{x_n}>$ is a tuple, and $\mathbf{1\le i_1,\ldots,i_k\le n}$ is a set of indices, then $\boldsymbol{\pi}_{\mathbf{i1,\ldots,ik}}\mathbf{(x)}$ denotes the tuple $<\mathbf{x_{i1}},\ldots,\mathbf{x_{ik}}>$.
- If **X** is a set, the $\wp\mathbf{(X)}$ denotes the set of all subsets of **X.**

Definition(W-process) A tuple $\mathbf{P = <T, N, C, E, \Phi, i, o, \Psi, \Delta, M>}$ is called ***W-process***, if

1. **T** is a finite set of ***types***. The set of values for $\mathbf{t \in T}$ is denoted by **DOM(t)** and is called the ***domain*** of **t**.
2. **N** is a finite set of ***activities*** having some priorities.
3. **C** is the finite set of ***transition conditions***.
4. The set $\mathbf{E \subseteq N \times N \times C}$ is the set of ***connectors*** with the following restrictions
   - **E** is *unified*: $\forall\mathbf{e, e' \in E : \pi_{1,2}(e) = \pi_{1,2}(e') \Rightarrow \pi_3(e) = \pi_3(e')}$.
   - The **G=(N, E)** graph is acyclic.
5. $\mathbf{\Phi : N \to F}$, where **F** is the set of all activity join conditions. The ***join condition of activity*** $\mathbf{A \in N}$ is defined as a Boolean expression $\mathbf{\Phi(A)}$ depending on elements of set $\mathbf{A^{\leftarrow}=\{e \in E \mid \pi_2(e)=A\}}$. Suppose $\mathbf{\Phi(A)\equiv 1}$, if $\mathbf{A^{\leftarrow}} =\varnothing$.
6. $\mathbf{i : N \cup C \to IV}$ is ***input container*** map where **IV** is the set of input variable tuples of activities and conditions. Each input variable is unique and belongs to any type from **T**.
7. $\mathbf{o: N \to OV}$ is ***output container*** map where **OV** is the set of output variable tuples of activities. Each output variable is unique and belongs to any type from **T**.
8. $\mathbf{\Psi : N \cup C \to E}$, where **E** is the set of activities and conditions of all possible implementations.
   The ***implementation of activity*** $\mathbf{A \in N}$ is defined as a map $\mathbf{\Psi(A)}: \times_{\mathbf{v \in i(A)}}\mathbf{DOM(v)} \to \times_{\mathbf{v \in o(A)}}\mathbf{DOM(v)}$. The

implementation of condition $\mathbf{p} \in \mathbf{C}$ is defined as a map $\mathbf{\Psi(p)}: \times_{v \in i(p)} \mathbf{DOM(v)} \rightarrow \{0, 1\}$.

9. **M** is an ***external memory***. Each variable from **M** is unique and belongs to any type from **T.** Let $\mathbf{A}^{\rightarrow} = \{\mathbf{e} \in \mathbf{E} \mid \pi_1(\mathbf{e}) = \mathbf{A}\})$ is the set of outgoing transition conditions from the activity **A**
10. $\Delta : \mathbf{N} \times (\mathbf{N} \cup \mathbf{C} \cup \{\mathbf{M}\}) \rightarrow \cup_{A \in N,\, B \in N \cup C} \wp(\mathbf{o(A)} \times \mathbf{(i(B)} \cup \mathbf{M}))$ is ***data connector map*** with following restrictions:
    a. $[\mathbf{A} \in \mathbf{N}, \mathbf{B} \in \mathbf{N} \cup \mathbf{C}] \Rightarrow \Delta(\mathbf{A}, \mathbf{B}) \subseteq \mathbf{o(A)} \times \mathbf{i(B)}$.
    b. $\mathbf{A} \in \mathbf{N} \Rightarrow \Delta(\mathbf{A}, \mathbf{M}) \subseteq \mathbf{o(A)} \times \mathbf{M}$.
    c. $[\mathbf{A} \in \mathbf{N}, \mathbf{B} \in \mathbf{N} \cup \mathbf{C} \cup \{\mathbf{M}\}, \langle v1, v' \rangle \in \Delta(\mathbf{A}, \mathbf{B}), \langle v2, v' \rangle \in \Delta(\mathbf{A}, \mathbf{B})] \Rightarrow v1 = v2$.
    d. $\forall \langle v, v' \rangle \in \Delta(X,Y), \mathbf{DOM(v)} = \mathbf{DOM(v')}$.

Definition(cyclic business process) The cyclic business process is defined as follows:

1. A tuple $\langle \mathbf{T, N, C, E, \Phi, i, o, \Psi, \Delta, M} \rangle$ as defined for **W-process.**
2. All cycles are localized cycles (the only point of cycles' intersection can be the cycle head).
3. $\mathbf{N_C} \subseteq \mathbf{N}$ is the set of activities, each of which is the head of a cycle. Suppose $\mathbf{K_A}$ is the set of activities, contained in the cycle having the head $\mathbf{A} \in \mathbf{N}$.
4. $\mathbf{C_C}^{\leftarrow}\mathbf{(A)} := \pi_3(\{\mathbf{e} \in \mathbf{E} \mid \pi_2(\mathbf{e}) = \mathbf{A} \;\&\; \pi_1(\mathbf{e}) \in \mathbf{K_A}\})$ is the set of inner transition conditions for $\mathbf{A} \in \mathbf{N}$.
5. $\mathbf{C_*}^{\leftarrow}\mathbf{(A)} := \pi_3(\{\mathbf{e} \in \mathbf{E} \mid \pi_2(\mathbf{e}) = \mathbf{A} \;\&\; \pi_1(\mathbf{e}) \notin \mathbf{K_A}\}))$ is the set of outer transition conditions for $\mathbf{A} \in \mathbf{N}$.
6. $\forall\, \mathbf{A} \in \mathbf{N_C}, \mathbf{\Phi(A)} \in \varphi_A^*$, where
$$\varphi_A^* := \{ \bigwedge_{1 \le j \le k} \bigvee_{1 \le i \le lj} pi \mid pi \in \{p', \sim p' \mid p' \in \{C_*^{\leftarrow}(A)\}\}\}$$
7. The set of inner join conditions for $\forall\, \mathbf{A} \in \mathbf{N_C}$ is
$$\varphi_{AC} := \{ \bigwedge_{1 \le j \le k} \bigvee_{1 \le i \le l_j} p_i \mid p_i \in \{p', \sim p' \mid p' \in \{C_C^{\leftarrow}(A)\}\}\}$$

We will assume that $\forall\, \mathbf{A} \notin \mathbf{N_C}, \mathbf{\Phi_C(A)} \in \varphi_{AC}$, $\mathbf{\Phi_C(A)} = 0$

$\mathbf{A} \in \mathbf{N_C}$, **A** can be activated $\Leftrightarrow (\mathbf{\Phi(A)(i(p_1), \ldots, i(p_{nA}))} = 1) \vee (\mathbf{\Phi_C(A)(i(q_1), \ldots, i(q_{mA}))} = 1)$, $\mathbf{C_*}^{\leftarrow}\mathbf{(A)} = \{\mathbf{p_1}, \ldots, \mathbf{p_{nA}}\}$, $\mathbf{C_C}^{\leftarrow}\mathbf{(A)} = \{\mathbf{q_1}, \ldots, \mathbf{q_{mA}}\}$.

Definition(process correctness) Let **P** be a business process. Let -α, β be two predicates depending on the state of the external memory **M** of **P**. Let us call α and β a precondition and a postcondition, respectively. In this case, **P** is correct with respect to α and β, if

$$[\alpha(\mathbf{M}) = 1 \Rightarrow \beta(\mathbf{MP}) = 1],$$

where **MP** denotes the external memory state after the execution of the **P** process.

Formal Verification Algorithm

The formal verification requires knowledge about the underlying IT management process (internal structure of tasks, data flow, etc.). Formal verification has to take into account not only peculiarities of process structures (Perumal and Mahanti 2007b, Koehler and Hauser 2004), but also data dependencies and, particularly, the data flow graph of a given process (Allen and Cocke 1976, Kostanyan and Varosyan 2008, Ammann and Offutt 2008). Two assertions have to be specified for the process. First, the process input assertion, called precondition, has to be satisfied prior to the process execution. Second, the process output assertion, called postcondition, has to be checked at the end of each process execution. The process is considered to be correct if the value of postcondition is "true" for all possible executions.

In general, insolubility (or exhaustion) hampers direct application of formal verification to complex cases. Therefore, the desire to apply a strict criterion must be neglected and replaced with finding effectively verifiable, acceptable conditions for verification. More explicitly, algorithms should be constructed, which are applicable to any object considered for verification. These algorithms must give one of the three answers: correct, incorrect, or unknown under restrictions on execution time. An algorithm is called partial-recognizing if it answers correct (incorrect) only for correct (incorrect) objects. A partial-recognizing algorithm (PRA) can answer "the correctness is unknown" in the case of a correct object.

Adopting the described approach to IT management process formal verification, one way to create a PRA is to approximate the input and output assertions of an IT management process by special language constructions called molds (Kostanian 1995, Shoukourian et al. 1996) Molds specify the form of relationships between variables at the input and output of an IT management process. Filling the form with concrete values results in a particular assertion described by a mold. In many cases, molds simplify and increase the effectiveness of procedures for determining IT management process correctness. It is possible to construct from an IT management process and its input assertion a special intermediate mold that describes a complete set of invariant relationships at the IT management process output. We call a relationship invariant if it is true after any IT management process interpretation/execution. An IT management process is correct if output assertion implies from the obtained intermediate mold.

This paper suggests an extension of the acyclic process verification algorithm (Kostanyan and Varosyan 2008) for the general case, i.e. a new PRA is suggested for verification of cyclic IT management processes (Figure 4).

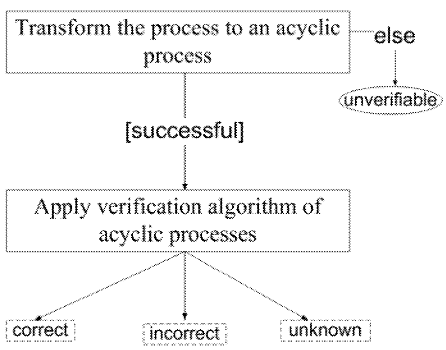

Figure 4: IT Process Formal Verification Approach

It is based on the idea of reducing the cyclic IT management process to the acyclic one, and then applying the formal verification approach of acyclic processes. The algorithm of the described approach, suggested for verification of cyclic business processes, is presented in

(Kostanyan et al. 2009) in more details. The reduction algorithm is based on the idea of interval graphs suggested by F.E.Allen and J.Cocke for analysis procedure of data flow graph (Allen and Cocke 1976).This idea, initially used in optimization of compilers, was used afterward in many other applications (e.g. Ammann and Offutt 2008).

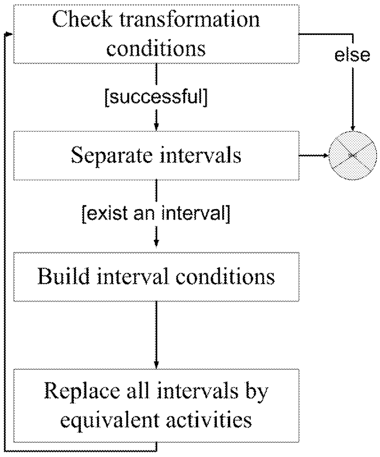

Figure 5: IT Management Process Reduction Approach

These are restrictions on a cyclic process to be reducible: the control flow graph of the process has to be a first order factor graph (Allen and Cocke 1976), data flow connectors connect an activity with another activity if they are also connected in the control flow graph; branching activities of a cycle have only 2 outgoing mutually exclusive transition conditions, the memory elements have single data connectors pointing on them. The general schema of the reduction approach is presented in Figure 5. The formal description of reduction algorithm is presented in (Kostanyan et al. 2009) in more detail.

Let the process has n activities, c control connectors, d data connectors. Suppose maximal numbers of the process activities input (output) container elements is $m(x)$ accordingly. Assume that the maximal number of the process activities incoming/outgoing control and data connectors is d_i /d_o and c_i/c_o correspondingly. A rough estimation of the complexity for the suggested approach is adduced bellow:

1. Check reducibility conditions- $n*(d_o+c_o)+n*c_o + m$
2. Separate intervals - $n*c_i$
3. Build interval conditions - $n*(c_i+c_o)$
4. Replace all intervals by equivalent activities - $n*(c_i + c_o + d_i + d_o)$

As a result, the reduction operation complexity would be estimated by $Est(red) = n* (3c_i+4c_o+2d_o+d_i) \approx n*4c \approx O(n^2)$ formula. Thus the cyclic process reduction algorithm is sufficiently effective (polynomial complexity) reduction algorithm. The suggested formal verification algorithm for the general case has polynomial complexity.

Simulation Algorithm

A concurrent simulation algorithm was developed for the process simulation. This algorithm makes it possible to increase performance by using computing grid structure to perform independent tasks simultaneously.

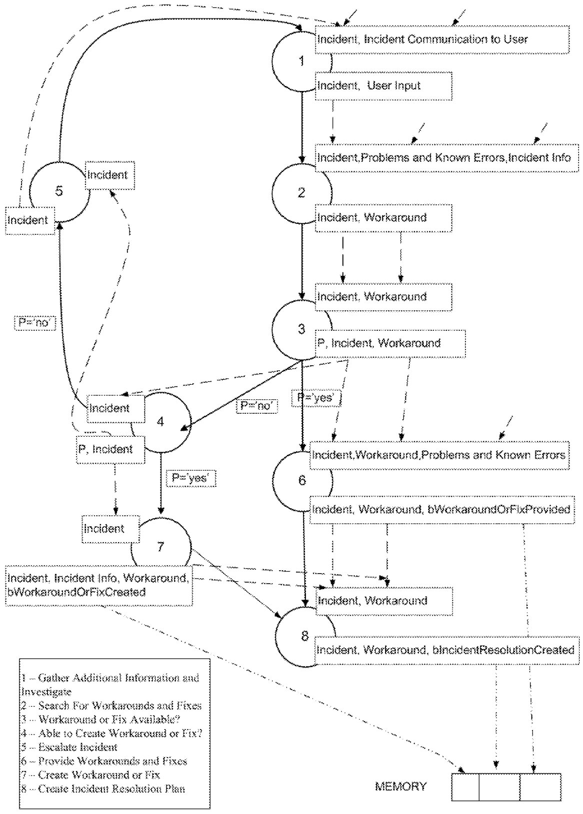

Figure 6: Investigate and Diagnose Incident Process Fragment

"Incident Management" template process from ITIL has been chosen as an example for implementation. Fragment of the process is shown on Figure 6. Operations 4 and 6 can be executed simultaneously, as well as operations 7, 5 and 8. Algorithm execution time was measured for different configurations of workstation cluster. The results of measurements are presented in the chart below (Fig. 7).

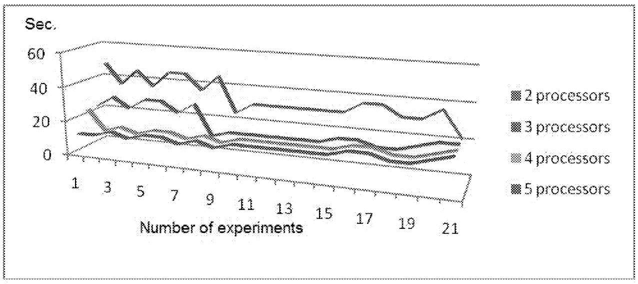

Figure 7: Algorithm Execution Time Estimation

IMPLEMENTATION

ITPDL: A Language for IT Process Description

To support application of formal methods to IT management processes a language is suggested and implemented for formal representation of IT management processes. Each process is defined by:

- An overall introduction describing goals, mission, scope, and key performance indicators (KPIs)
- A workflow
- People (Roles)
- Information (Work Products)

- Products (Tools) that help implement aspects of the process
- Invariant conditions

IT Management Process Tuner Tool

Figure 8 and 9 show the architecture and usage flow of IT Management Process Tuner tool, respectively.

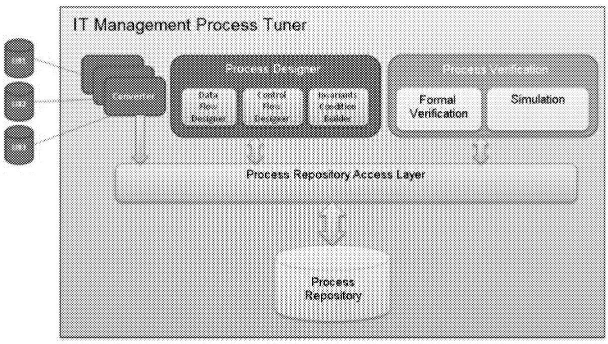

Figure 8: IT Management Process Tuner Architecture

ITMPT tool comprises from the following blocks:
- **Converters** for transforming existing vendor-dependent process library into ITPDL format
- **Process Tuner** for making changes to existing processes as well as creating invariant conditions.
- **Process Repository** includes all the processes that were transformed or created
- **Process Repository Access Layer** provides uniform access to process repository for all blocks. **Verification algorithms** for functional and structural verification of processes
- **Simulation algorithm** for simulation of processes

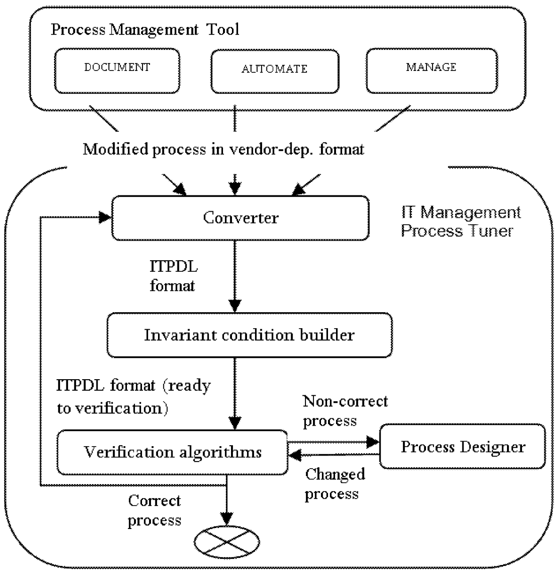

Figure 9: IT Management Process Tuner Usage Flow

CONCLUSION

This paper suggests a way of tuning the best practice processes to specific GRID configurations. The suggested approach is based on initial library of correct process templates basing on best practice processes and effective methods of their verification, after changes, i.e.. The method of verification is a combination of formal verification and fast simulation methods.

Future plans are connected with continuing this work in two directions. One direction is to build the set of IT management processes for managing computing grids. The other direction is to determine the range of application for the suggested method of functional verification within the framework of IT management processes.

REFERENCES

Allen,F.E. and J. Cocke. 1976. "A program data flow analysis procedure". *Communications of the ACM*, 19(3):137-147

Ammann, P. and J. Offutt. 2008. "Introduction to Software Testing". *Cambridge University Press*, ISBN 978-0-521-88038-1

Armenian Cluster for High Perf. Computation, www.cluster.am

Bi H. and Zhao J. "Applying Propositional Logic to Workflow Verification", *Information Technology and Management,* Volume 5, Numbers 3-4, July 2004 , pp. 293-318

Black, J.; C. Draper; T. Lococo; F. Matar; and C. Ward. 2007. "An integration model for organizing IT service management". IBM SYSTEMS JOURNAL, VOL 46, NO 3

Grid computing, www.gridcomputing.org

IT Infrastructure Library, IT Service Management, http://www.itil-officialsite.com.

Johnson,M.W.; A.Hately; B.A. Miller; and R. Orr. 2007. "Evolving standards for IT service management". *IBM SYSTEMS JOURNAL*, VOL 46, NO 3 (2007)

Keel, A.J.; M.A. Orr; R.R. Hernandez; E.A. Patrocinio; and J., Bouchard.2007. "From a technology-oriented to a service-oriented approach to IT management".*IBM SJ*, VOL 46,NO 3

Koehler,J. and R. Hauser. 2004. "Untangling Unstructured Cyclic Flows – A Solution Based on Continuations". *CoopIS/DOA/ODBASE (1),* pp. 121-138

Kostanyan, A. 1995. "A Problem of Verification for Linear Programs with Boolean Arrays", *Kibernetika i sistemny analiz*, Kiev, Ukraine, 1995, #5, pp. 87-94.

Kostanyan, A. and A. Varosyan. 2008. "*Partial Recongnizing Algorithm for Verification of Workflow Processes*". Proceedings of FUBUTEC'2008, pp. 89-94, Porto, Portugal

Kostanyan, A.; V. Matevosyan; S. Shoukourian; and A. Varosyan. 2009. "An Approach for Formal Verification of Business Processes". *Business and Industry Symposium (BIS'09)*, SpringSim'09*,* ACM Press, San Diego, CA, USA

Leymann, F. and D. Roller. 2000. "Production Workflow: Concepts and Techniques", *Prentice Hall Press* (2000)

Paul,C.J.. 2007. "The process of building a Process Manager: Architecture and design patterns". *IBM SJ*, VOL 46, NO 3.

Perumal, S. and A. Mahanti. 2007. "Applying Graph Search Techniques for Workflow Verification," *hicss*, p. 48c, *40th Annual Hawaii International Conference on System Sciences*

Perumal, S. and A. Mahanti. 2007. Cyclic Workflow Verification Algorithm For Workflow Graphs. Published in *"2007 BPM and Workflow Handbook"*, (2007)

Pfeiffer, J.-H.; W. R. Rossak and A. Speck. 2004. "Applying Model Checking to Workflow Verification," *ecbs*, p. 144, *11th IEEE International Conference and Workshop on the Engineering of Computer-Based Systems (ECBS'04)*, 2004

Shoukourian, S., A. Kostanian; V. Margarian; and A. Ashour. 1995. "An Approach for System Tests Design and Its Applications". *Proc. of the 13-th IEEE VLSI Test Symposium*, NJ, Princeton, USA, pp. 448-453, (1995)

Wynn, M.T.; H.M.W. Verbeek; W.M.P. van der Aalst; and A.H.M. ter Hofstede. 2008. "Business Process Verification: Finally a Reality!". Business Process Management Journal,

Xu,F. and Z.Yu. 2007. "A Workflow Verification Method Based on Calculus", *Proceedings of TASE 2007,* pages 188-196

Mobile Agent Optimization Analysis of Least Time Approach Versus V-Agent

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KEYWORDS

Mobile Software Agents, Message Broadcast Model (MBM), Message Delivery/Response Matrix (MDRM), Least Time Approach, Performance Analysis.

ABSTRACT

Agent Oriented Engineering (AOE) represents an exciting new means of analyzing and designing complex software systems. Mobile agents have proved as an effective solution in building wide range of computing distributed applications. Despite the research papers carried out, a number of disciplines concerning mainly performance optimization of mobile agent-based applications are still growing. In this paper, we have successfully developed an approach that computes performance optimization of mobile agent systems. This approach utilizes Master-Slave Design Pattern of mobile agent systems. The proposed approach is called the Least Time performance optimization which uses a new developed computing model, namely Message Broadcast Model (MBM). Basically, MBM manages messages between set of master agents carrying out tasks on a set of clients and corresponding slave agents receiving and performing tasks on servers. Each slave agent registers its working time given in milliseconds in message broadcast handler. We analyzed MBM using new types of matrices namely Message Delivery/Response Matrix (MDRM). Performance optimization is calculated based on Least Time approach and compared with another approach namely V-agent. Furthermore, we implemented a prototyping scenario of MDRM based on MBM. This approach is developed as a mean of exploiting analyses for parallel distributing computing.

INTRODUCTION

Computational architectural design models for distributed systems have been categorized into three design architectures: repository model, client/server model, and layered model (Sommerville 2006). Data is processed between different resources that incorporate multiple machines and numerous computing stages. Challenges of design models include performance, security, and flexibility.

Mobility model (Braun and Rossak 2004) (Cabri et al. 2004) is developed a massive model to overcome aforementioned models shortcomings. Several features were proposed to adhere mobile agents including: reduce network traffic, their ability to operate asynchronously and autonomously of the process they created them, and assist to construct more robust systems (Lange 1998) (Lange and Oshima 1998).

Mobile agent patterns (Yariv and Lange 1998) are emerging in the design of Agent Oriented Software Engineering (AOSE), and several of these patterns were given intuitive meaningful names such as messenger, notifier, and master-slave pattern. Master-slave pattern is a common task design model incorporated in a broad domain of parallel applications. This model is based on a divides and conquers fashion in which a master agent delegates tasks to one or more slaves that in turn are distributed throughout the system and work in parallel. Our proposed work is focused to develop a new approach that utilizes a computational model called, MBM[1]. This approach carries out computational algorithm of master delivery messages and slave responses.

Furthermore, Least Time approach is implemented throughout choosing the least slave message response time and then computes the total time for number of messages to be delivered by master agents working on clients to slave agents carrying out tasks on servers. This technique is compared with other approaches that used in the analyses of performance optimization for computing total time which uses V-agent algorithm. This approach gives the basis for analysis of performance and flexibility of mobile agent systems.

RELATER WORK

performance analysis is the foundation of performance debugging and optimization, comparison of systems, and extrapolation of properties of future systems (Marios and George 2000). Several authors have presented several techniques of performance optimization analysis for mobile agent systems (and performance of mobile agent applications. Mandwake and Patl 2008), developed a methodology for improving the performance of mobile agent systems through controlling of the optimum visited sequence of mobile agents to the target machines. The optimization of the visited sequence is based on the latency of the underlying network. A management task such as the configuration of a Differentiated Services domain could be used to test and evaluate the proposed methodology. In particular, it is demonstrated that when a mobile agent should act on a set of

[1] This research is sponsored by Applied Science University (ASU) and the Faculty of IT.

targets, the time required to perform a task is decreased if the visited sequence is decided based on the network latency. (Mandwake and Patl 2008) developed a computing model, called Mobile Agent Parallel Processing Computing (MAPPC) that uses a family of mobile agents. MAPPC uses a Matrix multiplication task and is divided on row wise basis. Based on a number of available servers and dimension of block size is assigned to each mobile agent. The MAPPC model experiment an implementation where small amount of data (matrix of size less than 100) was processed on remote servers (less than 3) gives little performance than large matrices on large number of servers.

MAPPC model uses master-slave pattern for mobile agents in which a slave agent does a given task using CPU resource of remote server. A slave agent constructs the message and embeds the result into it and sends it to the master agents proxy. The master agent is waiting results from slave agent that receives the message, extracts the results and combines all results together, it calculates the turnaround time for the computation which will be used to analyze performance. (Shrouf et al. 2008) proposed V-agent that utilizes master-slave pattern of mobile agents, which carries out an MBM algorithm to optimize the total time between set of master agents delivered tasks to slave agents that carry out some tasks based on slave agents broadcast time.

The main focus of this paper is to analyze the performance optimization using Least Time approach that utilizes MBM and set of master agents send messages to slave agents which respond and carry out tasks. This approach introduces an advanced technique which overcomes Free Area Mechanism (FAM) approach (Tarig 2007). Furthermore, our approach supports performance optimization perspective compared Decision Tree Learning (DTL) approach (Yasser et al. 2007). This paper uses samples of two data sets for Least time approach and V-agent.

RESEARCH OBJECTIVES AND MOTIVATIONS

Communication is the base mechanism for coordination and collaboration in mobile agent systems. However current mobile agent systems focus on content of messages, delivery and response, and time allocating, implying difficulties in activity coordination and performance.

To enhance message performance communication(Robert et al 2001) demonstrates an approach for mobile agent communication which can improve performance content filtering system and can unify several messages in a single one using D'agents.

The main objectives of this research are: study performance issues of mobile agent based systems and discover potential performance approaches. This paper addresses message performance optimization through coordination in mobile agent systems using different techniques and mathematical models founded earlier in operational research techniques. This approach proved advanced solutions to some basic mathematical models in optimization and reliability system measurements. Such approaches can be used to improve performance optimization in mobility systems.

MASTER SLAVE TASK PATTERN

Master slave pattern (Lange and Oshima 1998) is a parallel computing application in which master agents working on clients creates slave agents dispatch to remote servers. Slave agents visit specified server to perform the required task. Master agents connect with slave agents using master agents proxy and sends messages in a broadcast paradigm. A user, wants to perform the task, submits it to master agents then divide it into subtasks and assign it to individual slave agent. Master slave pattern involves:

A. Master Agents

These are task handlers in the system. They are created on set of clients. The user uses Java Execution Environment (JEE) platform consists of Tahiti server and Java runtime of Aglet development Kit. After the user instantiates interface, it creates slave agents, reads the database for the list of servers, and checks the availability of servers it sends the slave agents to those servers.

B. Slave Agents

Slave agents migrate and functioning on servers. They respond to master messages, at remote site slave agents receives multiple messages for given tasks and sends results to master agents by embedding it into message handler. Each message registered with the handler which is responsible to record its time received by the slave, and the corresponding slave, which sends the message and forward results to the master agent.

MESSAGE BROADCAST MODEL (MBM)

Consider set of clients C_k, involves set of master agents M_k, where $C_k=\{C_{1m1}, C_{2m2},\ldots\ldots\ldots, C_{kmk}\}$, furthermore, consider a set of servers S_n are distributed across network involves a set of created slave agents, $S_n=\{S_{1s1}, S_{2s2}, \ldots\ldots\ldots, S_{nsn}\}$. Suppose MD_{mi} is the total number of messages to be delivered from the master agent (m_i) to slave agents carrying out some tasks on server side, and suppose MR_{sj} is the total number of response messages that a slave agent (s_j) responds from all master agents in it's broadcast queue.

Furthermore, we proposed that total messages that to be delivered by all masters are equal to total response messages in broadcast messaging queue by slave agents, in other words

$$\sum_{i=1}^{k} MD_{mi} = \sum_{j=1}^{n} MR_{sj}$$

Now, suppose that t_{misj} is the estimated response time of a slave agent (s_j) performing a task on the behalf of a master agent (m_i) and λ_{misj} are number of messages delivered by a master agent (m_i) to a slave agent (s_j). Based on these assumptions, we proposed the Message Broadcast Model (MBM) that is based on the Message Delivery/Response Matrix (MDRM). MDRM involves: master agents, slave agents, message delivered by master agents, message response by slave agents, and allocation time of each slave agent. MDRM is shown in Table 1.

Table 1: Message Delivery Response Matrix (MDRM)

	S_{1s1}	S_{2s2}	……	……..	S_{nsn}	MD
C_{1m1}	$\mathbf{t_{m1s1}}$ $\boldsymbol{\lambda_{m1s1}}$	$\mathbf{t_{m2s2}}$ $\boldsymbol{\lambda_{m1s2}}$	…….	…….	$\mathbf{t_{m1sn}}$ $\boldsymbol{\lambda_{m1sn}}$	MD_{m1}
C_{2m2}	$\mathbf{t_{m2s1}}$ $\boldsymbol{\lambda_{m2s1}}$	$\mathbf{t_{m2s2}}$ $\boldsymbol{\lambda_{m2s2}}$	…….	…….	$\mathbf{t_{m2sn}}$ $\boldsymbol{\lambda_{m2sn}}$	MD_{m2}
. .	• •	• •	…….	…….	• •	. .
C_{kmk}	$\mathbf{t_{mks1}}$ $\boldsymbol{\lambda_{mks1}}$	$\mathbf{t_{mks1}}$ $\boldsymbol{\lambda_{mks1}}$			$\mathbf{t_{mksn}}$ $\boldsymbol{\lambda_{mksn}}$	MD_{mk}
MR	MR_{s1}	MR_{s2}	…….	…….	MR_{sn}	

Now, the MBM model follows a linear programming model (Shrouf et al. 2008) with set of equations:

- Determine the objective function.
- Set out model constraints.
- Validate model non negative values.

The objective function is given by equation (1), constraints given by equation (2) and (3) respectively, and non negativity condition is given by equation (4) as follows:

$$\min(t) = \sum_{i=1}^{k}\sum_{j=1}^{n} \lambda_{misj} t_{ij} \tag{1}$$

$$\sum_{j=1}^{n} \lambda_{misj} = MD_{mi} \quad i = 1,2,.....,k \tag{2}$$

$$\sum_{i=1}^{k} \lambda_{misj} = MR_{sj} \quad j = 1,2,.......,n \tag{3}$$

$$\lambda_{misj} \geq 0 \quad For\ all\ i\ and\ j \tag{4}$$

MBM SOLVING USING V-AGENT APPROACH

We present V-agent approach as given by (Shrouf et al. 2008) for mobile agent performance optimization. V-agent utilizes VAM (Frederick and Lieberman 2005), which gives an initial solution. VAM steps are:

- Find Penalty Time (PT) between two successive time values in each row and column.
- Choose the larges PT among rows and columns.
- Fill the cell with master message delivery and slave message response.
- Repeat the process until to fill all cells.
- Calculate the optimum time using equation (1).

The optimal solution using VAM gives an initial solution. This measures the performance optimization between master agents and slave agents coordination mechanism.

MBM SOLVING USING LEAST TIME APPROACH

We present an approach which gives an initial solution for message performance optimization among a set of master agents working on clients and corresponding slave agents working on a set of servers. This approach is based on the definition of MDRM of MBM model stated earlier. The Least Time approach for mobile agent performance optimization starts by assigning number of messages λ_{misj} according to the least time t_{misj} allocated by a slave agent and a master agent among all rows and columns. If two slaves have the same response time t_{misj} , then we can choose any starting slave response time. The corresponding master agent on a client C_{kmk} should assign all messages MD_{mk} to slave agent on S_{nsn} based on slave total message response MR_{sn}. We continue an iterative process to assign all messages by master agents based on choosing the next least time. Note that master agent should deliver exact number of messages according to slave agent capability. Finally, we calculate the total time with reference to equation (1) which gives the optimal performance time among all slaves. This is considered as an initial starting solution for performance optimization measurements between mater and slave agents.

IMPLEMENTATION SCENARIO USING V-AGENT

V-agent approach works on MDRM definition, which utilizes results from master agents to slave agents coordination tasks in message broadcast handler. Suppose we define set of four master agents {m1, m2, m3, m4} with set of total message to be delivered 4000 as {1000, 1000, 1000, 1000} to set of three slave agents {s1, s2, s3} with total message response {1000, 1200, 1800} respectively. The allocated slave message response time of one message in milliseconds is given in Table (2).

Table 2: MDRM Implementation Scenario

	S1	S2	S3	MD
m1	10 λ_{m1s1}	9 λ_{m1s2}	8 λ_{m1s3}	1000
m2	8 λ_{m2s1}	6 λ_{m2s2}	11 λ_{m2s3}	1000
m3	10 λ_{m3s1}	3 λ_{m3s1}	5 λ_{m3s3}	1000
m4	7 λ_{m4s1}	9 λ_{m4s1}	8 λ_{m4s3}	1000
MR	1000	1200	1800	4000

This table shows total master agent's messages to be delivered to slave agents based on response message time, and number of messages to be assigned from each master agent to slave agents. This can be done by calculating values of { λ_{m1s1}, λ_{m1s2}, ……., λ_{m4s3} } using V-agent. We start the process by computing PT amongst rows and columns leading to choose the largest PT, if more than one PT values are equal, then V-agent choose any PT. Therefore, the calculated PT is 3 in the second column is choosen. V-agent assigns messages between the third master and the second slave agent (m3, s2). Therefore, V-agent allocates 1000 messages from m3 to s2. The remaining messages in the queue of slave agent s2 are 200. Therefore, m3 completes the first process.

V-agent computes the second PT amongst rows and columns. Now, it picks the second column with PT value (3). V-agent will choose the smallest allocated time in that column (6), and it optimizes the total messages between (m2, s2). Therefore, V-agent assigns the remaining messages to s2 and m2 has 800 messages to be delivered in the next process. V-agent iterates the remaining values and comes to the conclusion that all master agents completed the messages to all slave agents as shown in Table (3).

Table (3): MDRM Message Optimization Using V-Agent

	S1	S2	S3	MD
m1	10	9	8 1000	1000
m2	8 800	6 200	11	1000
m3	10	3 1000	5	1000
m4	7 200	9	8 800	1000
MR	1000	1200	1800	4000

The performance optimized time is computed according to equation (1) as follows:

t= 26400 milliseconds (ms)

The performance optimization time is given in Figure 1.

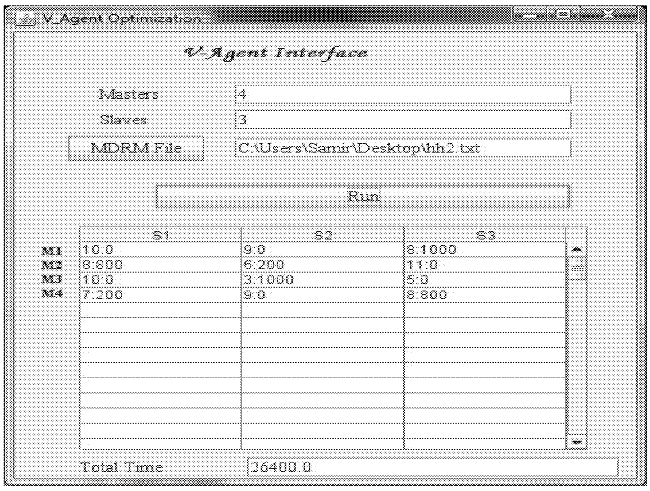

Figure (1): MDRM Optimization Using V-Agent

IMPLEMENTATION SCENARIO USING LEAST TIME APPROACH

We carry out performance optimization (minimized time) using Least Time approach based on Table (2). Least Time approach starts the process by considering the least allocated time, which is (3 ms) assigned by slave agent (s2). The corresponding master agent (m3) assigns 1000 messages to s2. The remaining messages are reduced by slave agent (s2) to 200. The next least allocated time is (6 ms) and the master agent m2 assigns the remaining 200 messages to slave agent s2. Now s2 completed all messages. The process is an iterative process performs until all master agents deliver all messages to slave agents. Note that if two allocated times are equal, the master agent will choose any of slave agents randomly. This will be considered as a malfunction in this approach. The final calculations is given in Table (4).

Table (4): MDRM Optimization Using Least Time Approach

	S1	S2	S3	MD
m1	10	9	8 1000	1000
m2	8	6 200	11 800	1000
m3	10	3 1000	5	1000
m4	7 1000	9	8	1000
MR	1000	1200	1800	4000

The performance optimized time is computed using Least Time approach according to equation (1) as follows:

t= 28000 milliseconds (ms)

The performance optimization time is given in Figure 2.

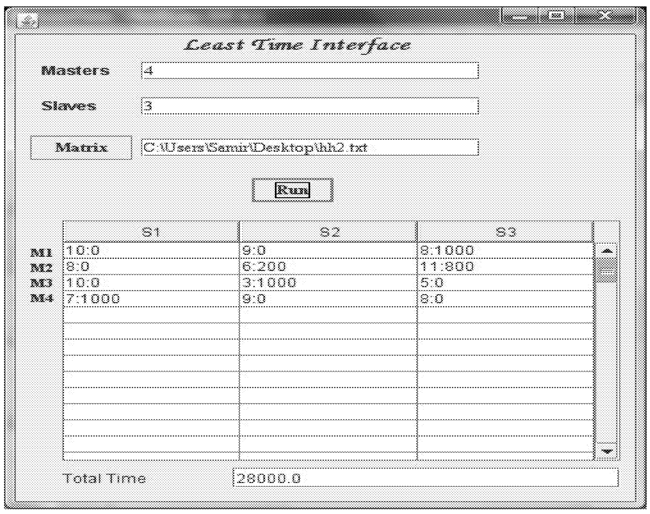

Figure (2): MDRM Optimization Using Least Time

PERFORMANCE OPTIMIZATION ANALYSIS

We highlight results from two different data sets. The analysis approach is base on number of slave agents, master agents, and disparity of slave agents response time. We calculate the variance σ^2 , which give messages disparity between two data sets. The first data set is given in Table 5, and indicates that V-agent performance optimization is better than Least Time approach when the variance σ^2 is small, while the second data set is given in Table 6 and indicates that V-agent performance optimization analysis is increased when σ^2 is quite larger than the first data set. Both data sets figure out that V-agent performance optimization is better than Least Time approach. Time is calculated in milliseconds (ms).

Table (5): First Data Set Analysis

Master x Slave	σ^2	Least Time	V-Agent
7m x 4s	4.452	88000	87800
5 m x 5s	4.240	51800	50800
4m x 7s	2.658	77500	75500

Table (6): Second Data Set Analysis

Master x Slave	σ^2	Least Time	V-Agent
7m x 4s	6.158	71400	66300
5 m x 5s	6.681	48800	45100
4m x 7s	6.811	70000	65500

The performance optimization analysis between V-agent and Least Time approach for the two data sets is shown in Figure 3.

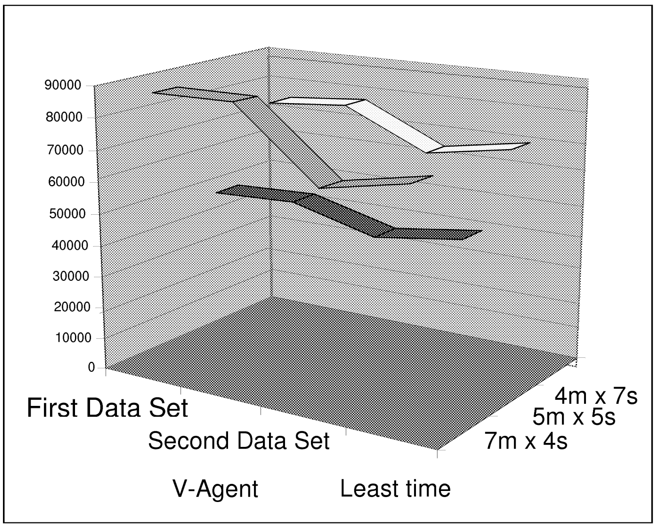

Figure (3): Performance Optimization Analysis

CONCLUSION AND FUTURE WORK

In this paper, we have developed a computational model for mobile agents, namely the Message Broadcast Model (MBM). This model utilized a set of master agents working on clients deliver messages to set of slave agents carrying out tasks working on servers. We have reported two different approaches for MDRM solving namely: V-agent and Least Time approach. A comparison between these approaches comes to a conclusion that V-agent optimization gives better solution than Least Time Approach.

We will comment some future trends based on MBM as follows:

- Analyze new approaches for mobile agents performance optimization using advanced approaches such as stepping stones (sinuous path) and coefficient of multipliers.
- Compare results of different approaches to V-agent approach.
- Build advanced design patterns namely Optimization Design Patterns for mobile agent systems.

However, optimization patterns are the next step for the communication that we should developed to support mobility concepts, thus providing more support for the development of distributed system applications that may benefit from code mobility.

We will extend this work to extract optimization design patterns. These patterns, and more significantly the skeletons, will be extracted to ensure the reliability and performance for mobile computing systems.

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REFERENCES

Braun, P. and W. Rossak. 2004. " Mobile Agents: Basic Concepts and the Tracy Toolkit". *Centre for Intelligent & Multi-Agent Systems, Morgan Kaufmann publishers, Australia.*

Cabri E.; L. Ferrari; L. Leonard. @004. "Towards the Use of Mobile Agent Systems". *Proceedings of 13th* IEEE International Workshop, *Enabling Technologies Infrastructure for Collaborative Enterprises.* 27-32.

Frederick S. and H. Lieberman. 2005. "Introduction to Operations Research". 8th edition, McGraw-Hill Education, USA.

Lange D. 1998. "Mobile Objects and Mobile Agents: The Future of Distributed Computing". *Proceedings of ECOOP'98 Conference,* Belgium.

Lange D. and M. Oshima. 1998. "Programming and Deploying Java Mobile Agents with Aglets". Addison Wesley Inc. USA.

Mandwake K. and G. Patl. 2008. "Performance Analysis of Parallel Server Versus Parallel Mobile Agent Model". *Proceeding of World Academy of Science Engineering and Technology. PWASET* Vol. 28: 374-377.

Marios D. and S. George. 2000. "A Performance Analysis Framework for Mobile Agent Systems". *Proceedings of the 4th International Conference on Autonomous Agent.* Cyprus.

Robert S.; C. George; Kotz D.; A. Ronald; R. Rus. 2001. " D'Agent: Applications and Performance of Mobile Agent Systems*", Report* , Thayer School of Engineering, Dartmouth College, USA.

Shrouf F.; Eshtay M; Hymdan K. 2008. "Performance Optimization for Mobile Agent Broadcast Model Using V-Agent". *International Journal of Computer Science and Network security,* IJCSNS, Vol. 2, No. 2; 285-290.

Sommerville I. 2006. "Software Engineering" 7th edition; Person Education Limited. USA.

Tarig A. 2007. "Increasing Mobile Agents Performance by Using Free Area Mechanism". *Journal of Object Technology;* JOT. Vol. 6; No. 4.; 125-140.

Yariv A. and D. Lange. 1998. "Agents Design Patterns: Elements of Agent Application Design". *Proceedings of Autonomous Agents*; ACM Press.

Yasser K.; Hesham A.; Elmahdi N.; Allola S.; Ahmad H. 2007. "Optimizing Mobile Agents Migration Based on Decision Tree Learning". *Proceedings of World Academy of Science Engineering and Technology;* PWASET. Vol. 22: 564-570.

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TOOL BASED ANALYTICAL SUPPORT FOR PRACTICAL PROFESSIONAL SOCCER TRAINNING

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KEYWORDS

Wi-Fi, Real-Time Tracking, Business Intelligence, Soccer Analysis.

ABSTRACT

Human observation and memory are not reliable enough to provide accurate and objective information from athletes in high-performance environments. In this context analysis tools constitute an important instrument for professional coaches, as they provide information on player's behavior statistically compiled. Most of the tools presented for the soccer universe, offer non-real time information and, with the hardware devices being quite costly. In many cases these systems (specially camera based solutions) also present some technical issues mainly in what concerns occlusion and computational demands.

This research work presents a real time soccer analysis system based on a Wi-Fi location approach that can be used by a soccer coach in a training session or even a match. Using a Wi-Fi network, inexpensive tags and a positioning engine on top of it, this portable system provides a visualization tool for such data on a real time basis.

The results are quite satisfactory, because this system was able to track the players during a training exercise and display this data on a real time bases and it was also able to provide information on players' movements and their interaction all over the exercise.

INTRODUCTION

Collective sports' games (CSG) appeared in the 7th century b.c in Colombia when the Inca civilization played a game called *Pok ta Pok* which is believed to have many similarities with basketball. In the *Pok ta Pok* game the field is constituted with two baskets located at three or four meters of the ground. The main goal was to pass a ball throw those targets without using the feet or the hands. Since then many other games emerged and in the 19th century the CSG hit its apogee with many participants playing them all over the world (Bayer 1994).

Nowadays there are more than two hundred CSG and in some cases one game might have the same name but different rules in distinct world regions. In order to classify these games a systematization process has been conducted in the recent years (Dobler 1989) (Read and Edwards 1992). It consists inn grouping the games having into account different sets of characteristics such as: *ball shape, type of the field (indoor or outdoor) and its regions*, *game rules*, *definition of opponents and teammates* etc.

The football or Soccer (designation used in North America) is a CSG that appears, as we know today, in the 19th century in England (football history 2008). One of the game's characteristics is that the players have the possibility to make real time choices, having the restrictions imposed by the rules, defined in a training session or in a professional competition, always in mind. This point is an element of freedom and consequently creativity. This reality should be managed by another individual called Coach whose purpose is to train the team for matches. In the literature many are the authors that tried to define Coaching. For Hughes (Hughes et al. 2001) coaching a soccer team is mainly a task of enhancing performance by providing feedback about the performance of the athletes and team. This performance may be measured having in mind different perspectives like: Physical, Technical, Tactical and Psychological. Although these points of view are extremely relevant for the game, tactical perspective is one that has occupied the academic society over the several years. The game's tactical analysis allows the coach to identify the relationships amongst play events, considering not only the individual but also the collective factors. These performance indicators reflect the importance of teamwork, pace, fitness and movement, and therefore to target strengths and weakness (Hughes and Bartlett 2002). Human observation and memory are not reliable enough to provide accurate and objective information from athletes in high-performance environments. Consequently, measurement tools constitute an important instrument by providing information about movement, statistical compilation of game events.

More then offline tools, the use of real time soccer systems provide the coach one opportunity to change some tactical or even technical aspects in a training session or in a real game situation. The majority of tools that exist in the market are very expensive and in some cases still present some technical issues like occlusion problems. This research work presents a platform that could be used for a coach in a training session or even a match. It is capable to automatically calculate the full path of a player in the field in a specific interval of time, the most populated zone in field all over a game allowing the coach to review the performance of his team. Using a Wi-Fi network and a positioning engine on top of it, this system provides a visualization tool for such data on a real time basis. This information includes fully scalable concentration grids, a vision inference assuming that the tracked entities are associated with soccer players. In addition to what was exposed the system also works as a statistical collector meaning that it is possible to use data mining techniques predicting and categorizing typical player paths and also detecting their behavior patterns all over the game.

This paper is organized as follow. Section 2 describes the current state of the art regarding the most relevant approaches concerning CSG specially related with soccer, section 3 presents an overview of the system's global architecture and describes some of its most relevant modules and details; section 4 exposes the results obtained from one system's instantiation; and finally, in the last section, conclusions are presented and future work trends are discussed.

STATE OF THE ART

Nowadays the key factor in a soccer club's life is the game results. They determine-represent the success of the club and in many cases the coach's future. Because of that club coaches need to have maximum technico-tactics information about the game events and the way that it was played by the players (Assfalg et al. 2003). Currently many are the computer systems that support coaching decisions before and after the game (Lames and Hansen 2001). These type of systems may be divided in three distinct groups: performance evaluation, strategy development and real time competent assistant system. These last are the most complex ones because they involve some particular features like real time objects tracking, identification and classification of player movements and game events detection. In order to build an indispensable tool for a coach, these systems should be automatically capable of recognizing intentional activities in a multiagent environment with continually acting agents.
In the next subsections a group of generic of-the-shelf and academic tracking systems shall be presented.

Generic Tracking Systems

In the literature there are many generic tracking systems that emerged over the past few years. These solutions are divided in two distinct groups: image based and non-image based.

Non-Image Based Systems
The Global Positioning System (GPS) is a satellite based solution that began being used by the U.S military forces for the planning of their operations particularly in arid and mountainous terrains. Since the 80's this technology became available for general public use and today it is normally used to do real time tracking analysis of different types of vehicles and as a base to analyze their motion (Yu 2005)(Nejikovsky et al. 2005). The Radio Frequency Identification (RFID) is an automatically wireless identification method that is capable of tracking objects and even people using radio waves. In terms of the required hardware, this technology uses a receiver and a set of tags which could be classified in: passive tags that are only detectable within a range lower than 13 meters of the receiver active tags that can be found within 40 meters of the receiver but need to have their own internal source power. Although the use of this technology could be an interesting solution for some areas, the high cost of the receiver and the active tag's average unit price is still an issue (C. et al. 2007). Wi-Fi is the name given for a popular wireless networking technology that uses radio waves to provide wireless high-speed Internet and network connections. Having this technology as a base it is easily to create a wireless data network that could be used in historical urban environments, academic campus etc. This technology could be used also for designing a tracking system. By reusing the wireless data network and it is possible to create a tracking system on top of this infrastructure. Another advantage of this approach is the possibility of tracking an object using only a single access point though in this particular situation the precision will diminish due to the lack of signal triangulation. By comparing this last with other technologies the risks of occlusion and signal loss in this kind of approach can be considered very low mainly in environments that present low levels of metal concentration (Mingkhwan 2006). Bluetooth is a wireless protocol present in almost mobile phones in the market. Although this protocol could be used in a tracking system, the high battery consumptions (Jappinen and J. 2007), the short coverable area and the non-transparent connection establishment process transform this approach inadequate for an efficient tracking system.

Image Based Systems
Thermal Signature is one of the most expensive tracking technologies existing in the market. It consists in detecting thermal signature of the objects tracked. The main purpose of these solutions is the reconnaissance and processing of thermal images. Although these systems present good results in some environments like oceans (within the objective of tracking living entities) (Raizer 2003) the high cost of the equipment and in some cases the inexistency of a detectable thermal signature restricts the use of these kind of systems to a very controlled set of situations. Multi-Camera video surveillance is the most popular tracking technology. In terms of hardware required this technology utilize a set of cameras spread in a trackable environment and a particular network. Despite being used in distinct scenarios some important issues still remain. The need to have high resolution equipment, dedicated network and the computational demands are still major problems that researchers have trying to optimize by using overlapping camera views (Javed et al. 2003)(Kettnaker and Zabih. 1999). In terms of generic tracking solutions and as a conclusion, all approaches have their strengths and weakness. Having in mind the characteristics of the CSG the best alternative seems to be a Wi-Fi based system. The competitive tag cost (that could be put for instance in a player shirt) and the high level of accuracy (in average less than 3 meters) shall constitute an important advantage. Another huge advantage is the fact that this technology is almost immune to the majority of occlusion problems that affect other approaches. Another technology that could constitute a good solution is the RFID based one. In spite of the fact that this technology requires standardization and consequently the cost of equipment will fall out (specially the receiver), the use of active tags could allow the increase of coverable area and accuracy levels have already reached good values. In spite of this, occlusion issues, related with liquids and metal still persist. Multi camera surveillance systems are also quite common. In this kind of system some problems still remain like the camera's cost, the computational demands and the occlusion problems that constitute a very important factor that ought to be optimized.

The other approaches like Bluetooth, GPS and thermal signature are not applicable in the CSG universe.

Sports Video Analysis

One of the major research areas in the CSG is the sports video analysis. In football/soccer domain researchers had focus their work in problems like shot classification (Gong et al. 1995), scene reconstruction (Yow et al. 1995), structure analysis (Xie et al. 2004)(Xu et al. 2001), event extraction (Baillie and Jose 2003)(Naphade et al. 1998) and rule-based semantic classification (Qian and Tovinkere 2001). These approaches used the image transmitted by the television and recorded them for posterior processing (after the match ended). These kinds of systems are categorized by Ekin (Ekin et al. 2003) in two main groups: cinematic and object-based ones. The object based uses algorithms to detect objects in a video while the cinematic uses features from video composition and produce rules.

Cinematic Approaches

Xu et. al (Xu et al. 2001) present a cinematic approach using for it the feature *dominant color ratio* to segment video. They defend that video reports should focus on play yard to extract game situations. Xie et. al (Xie et al. 2004) used a Hidden Markov Models approach to detect two restricts events: play and break, in a video game. The complexity of this process is higher than in other sports like tennis or volley because for instance in soccer it is hard to determine if the game is stopped by a decision of the referee or by other highlights of the game-goal, corner, kick, shot, etc. Other works like (Ren and Jose 2005) tried to expand Xie's work and detect more game events like focus and replay in order to define new features/structures that they called *Attack*.

Object Base Approaches

The object base approach demands more computational resources but it allows more high-level domain analysis. In order to detect a large number of game events the work developed by Gong et. al (Gong et al. 1995) analyzes the ball's trajectory and the relationship between the players' moves over the match. In the literature there are also many works that tried new approaches like merging audio and video information (Baillie and Jose 2003). Although this kind of approach could constitute more high-level domain analysis one big issue is the asynchronies between audio and video queues.

Real Time Tracking Systems

Over the past few years new approaches appeared that use a multi camera tracking system to track players which promote new kinds of features like a near real time analysis. By comparing with classic approaches analyzed in the previous subsections, this system uses a fix number of stationary video cameras placed in a traceable environment. This type of approach increases the overall field of view reducing the dynamic occlusion problems and improves the accuracy and robustness of the information collected. Cai and Aggarwal (Cai and Aggarwal 1996} and Khan et. al (Khan et al. 2001) track the object using the best view camera and if the trackable object leads the field of view they change it to a neighbored camera. Other authors like Stein (Stein 1998) and Black (Black et al. 2002) assume that all trackable objects are in the same plane and compute the homography transformation between the coordinates of two overlapping images captured with uncalibrated cameras. In the Xu et. al (Xu et al. 2004) work eight cameras were used and were calibrated in a ground plane coordinated system using Tsai's algorithm (Tsai 1986). Unfortunately this work presents some technical difficulties like problems with sparse landmarks in the coverable area that decrease the accurate calibration and data association and situations involving more than two players grouped in the same game region.
Summing, in CSG and more specifically in soccer the unique tracking systems that already exists in real environments are camera based. As demonstrated previously these systems still have to optimize some features like occlusion problems, computational demands, material cost and lack of portability.

PROJECT DESCRIPTION

In this section, the undertaken project is described in detail in what regards its several components and analysis perspectives. Having this in mind, the electrical infrastructure is detailed and after that the system's global architecture is depicted, in order to have an overall glimpse. The database model is further explained and the final two subsections are dedicated to the tools' individual description.

Electical Infrastructure

Most of professional soccer coaches state that the training session should have the same length as a conventional soccer match-ninety minutes. Consequently any training support system should stay active for all of this period. To fulfill this goal an electronic system was designed. In this approach a conventional 45A car battery is used directly connected to a 600w UPS. The UPS battery is also connected to the car battery in order to increase the autonomy of the system. This electrical infrastructure (Figure 1) is capable to provide power for more than 120 minutes. In order to increase the WI-FI network's density, a star toplogy approach is used. A router is connected directly to the battery's electrical extension and it is placed behind the goal. The access points (APs) were placed in specific points of the penalty box as shown In Figure 1.

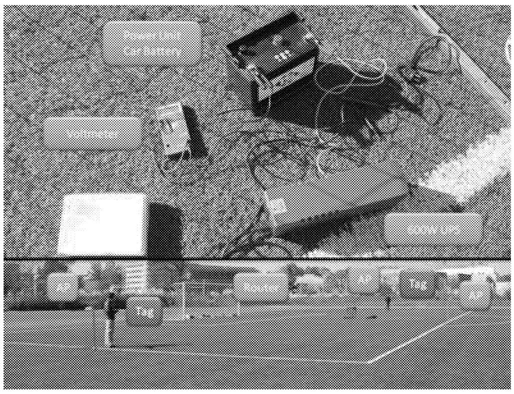

Figure 1: Electical Infrastrucure and WI-FI Network

Global Architecture

In this subsection the system's global architecture will be illustrated as well as of its modules and how they interact and therefore extract not only system components dependencies but also information flow analysis. All of the system's components and their relationships are exposed in Figure 2.

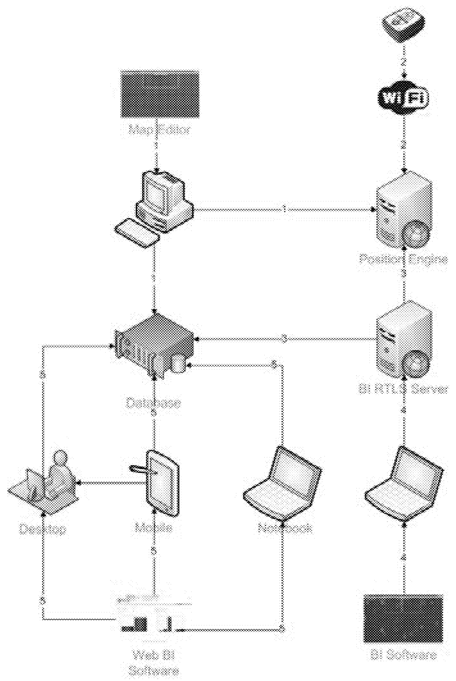

Figure 2: System's Global Architecture

Having the above mentioned in mind, and paying a closer attention to the numbers in figure, one is able to identify the system's modules as follows: Offline map editor; Wi-Fi enabled localization tag; Position Engine; Database for data integration and storage; Real-time monitoring application and Web enabled real-time and historical business intelligence. Although most of these elements are object of further explanation in the next subsections, one ought to undertake a brief description of those whose nature is not obvious and, in order to, clarify their interaction.

The first action, that ought to be conducted, in offline mode, consists in conducting a complete map creation-edition. The user shall specify, amongst other details, depicted in subsection Map Editor, the image file representing the soccer field layout and the used scale. This information is compiled in a XML file for both the position engine and real-time monitoring tool and submitted to the mentioned database for the historical BI application. The Wi-Fi tag consists in an active 802.11 a/b/g board with a couple of power batteries attached. These are configured to connect to a specific Wi-Fi network – security, DHCP but another network configurations are also possible – in order to directly communicate with the position engine. By using this kind of wireless technology, it is possible to reuse partially or totally the spot's arena network infrastructure, having only, for special requirement, a high density of access points as the accuracy naturally increases with this factor.

The used position engine periodically collects data from the tags and updates their position against a pre-loaded localization model. This model requires a previous offline site survey for measuring Wi-Fi signal strength and for network items – routers and access points – precise localization. The engine is also web-enabled and supports a HTTP/XML API so that third-party applications can interact with it, therefore accessing localization and status information regarding each individual registered tag.

Using this communication protocol, the developed real-time monitoring server is responsible for gathering, at a specific periodicity that typically equals to the position engine frequency – every tag's valid location data. With this information, this module is directly responsible for updating the database and caching the session's data for the real-time monitoring application.

Having the continuous up-to-date database as a solid information reference, it was possible to enable both real-time and historical business intelligence applications. For real-time knowledge extraction, it was only used data referring to active sessions, for historical analysis, and delegating all the process effort to the database engine, specific and dynamic time windows were used to filter data. Despite the additional explanations that are given in subsection Real-Time and Historical BI Application, the versatility of such application must be referred as it congregates both web-enabled features and zero data process as it is all delegated to the database engine and allocated in a dedicated server – enabling its usage in a wide range of devices, including PDAs and mobile phones, alongside with traditional notebooks and desktop computers.

As a synopsis, one might refer the system's architecture as fairly distributed, where offline information regarding soccer field layout and wireless network definitions team up with a real-time web-enabled position engine, which enables third-party applications to collect and store data, so that diverse specific end-users can access both real-time and historical knowledge in a wide range of equipments, therefore enhancing coaching efficiency levels.

Database Model

In this subsection, the designed database model is revealed and justified. Having into consideration the specific reported system's application in the soccer domain – usually characterized for multiple player movements all over the field combined with the project's idiosyncrasies – specifically in what concerns to localization tracking frequency – the database model paradigm followed consists in a hybrid form of a data warehouse star architecture with a slight normalization *flavor*, as illustrated in Figure 3.

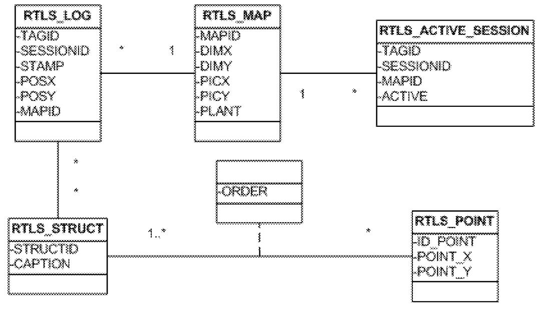

Figure 3: Database Model

Regarding the strong star model, it is supported for the high data production levels, and perhaps most important, the fact that all data insertions are machine responsibility, as depicted in the above subsection, therefore preventing human error. It is also vindicated by historical analysis need that may cover hundreds of thousands and even millions of records. On the other hand, some database normalization was introduced in order to cope with real-time requirements that would not be compatible with computing hundreds of records out of a table with millions of records, in a continuously systematic way. Another argument in favor of database normalization resides in the soccer's field layout. Referring to specific database model items, one shall point the central relevance of *rtls log* as central table responsible for storing all localization data. For each pair of tag/session identification, a particular position is recorded in a given layout with a specific timestamp. The concept of session may be different in each training session according to coach's decision. A new session could be related to three distinct situations: a player substitution (when a player is substituted by a colleague), a player out of the field (for instance to receiving medical assistance) or other situation when the player is out of the limits of the region that was defined by the coach for a specific situation in training session.

In order to achieve real-time requirements, some redundancy has been introduced in what concerns active session identification, so that active players identification could be easily, and most important, efficiently retrieved.

Map Editor

Map Editor is a traditional, network enabled, desktop application responsible for complete soccer field layout definition. The soccer coach shall open an image file and provide the interface with the drawing scale – in order to convert pixels to meters and vice-versa. Afterwards, the tool offers the possibility to pinpoint and draw, over the original layout, spawn areas – concept that will allow the detection of new sections. Once the layout is completely defined, the coach is able to save map characterization in a XML file in any available location and/or commit it to a specified database – with the previously described database model implemented.

The XML file will be an input for both the position engine and the real-time monitoring server, and, on the other hand, the committed database information is ground for historical computation and analysis.

Summarizing, the Map Editor constitutes itself as an auxiliary tool, vital for system's setup and dynamic enough to cover all the analyzed soccer field. Its dual output enables a flexible usage for several system components and, simultaneously, due to XML openness, enables third-party development and integration.

RESULTS

The results exposed in this section concern to the data gathered over a training exercise conducted with four human players in a real soccer field's penalty box with its dimensions as well as the goal's as recommended by the Federation Internationale de Football Association (FIFA). The exercise's purpose was to train a player's shot accuracy after receiving a pass from a winger. For that matter a goalkeeper, two wingers and a striker participated in this experience having each of them a Wi-Fi tag attached to their shirts. The penalty box was also divided in a 10*4 grid for calibration purposes and also to guide the site surveying process. The following picture (Figure 5) exposes how the exercise was conducted.

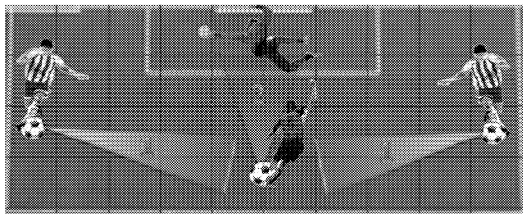

Figure 5: Soccer Exercise Conducted

To clarify the Wi-Fi network's density one ought to first specify the access points' positioning. A router was placed behind the goal as well as the batteries and the entire electrical infrastructure described in the previous section. The remaining three access points were also used and positioned over the center of the remaining lines that define the penalty box (excluding the one which contains the goal line). To maximize the signal's strength all the Wi-Fi devices emitting a signal were put on top of a structure that allowed them to gain 1.20 meters of height. They were also put twenty centimeters away from the real lines so that the players' moves were not affected by their presence. Figure 6 shows the signal's strength and noise levels on this particular scenario:

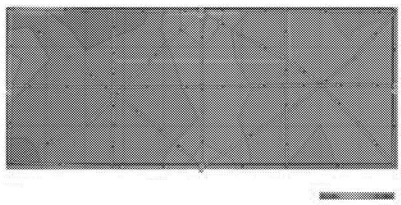

Figure 6: Signal Strength and Noise for WI-FI Network

Since this is an outdoor environment the authors believe that the gathered noise values are the main cause for the error on the player detection because they are not being compensated by refraction and reflection phenomena which are typical in indoor environments. One ought to point out that this test was conducted with high-end devices and so there is a high probability of diminish the noise's impact just by changing the hardware to high-end artifacts, as their value mostly differs on the applied power on signal emission.

Even so, the next figures clearly demonstrate that the system was able to track the players during this exercise which lasted about thirty minutes. For instance, on Figure 7, showing the box's density over the entire exercise with the scale depicted at the bottom of the picture, one can observe a red cell on the goal area which undoubtedly corresponds to the goalkeepers' presence waiting for the striker's shots. The neighbor cells are also highlighted as the goal keeper moved a bit during the exercise in order to better cover the striker's shots on goal. The other highlighted cells demonstrate how the other three players moved during this training session.

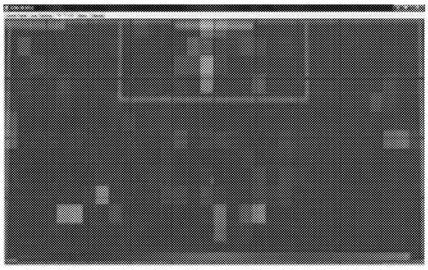

Figure 7: Box density over an exercise

Figure 8 shows a real time screenshot of the player density where one can observe the wingers' position after having one of them pass the ball.

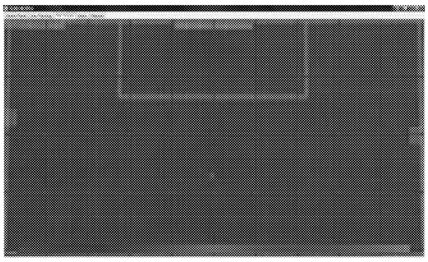

Figure 8: Player density in the game field

And finally on Figure 9, one can observe the left winger's and striker's position during a pass. On this particular figure the player's are represented as blue dots over the field. In this case the error between the obtained position and the real one did not exceed two meters for each player, which also justifies the fading green cells on the box's corner (shown on Figure 7) as the wingers could decide from where they wanted to perform the pass as long as their distance to the box's limits did not overcome three meters.

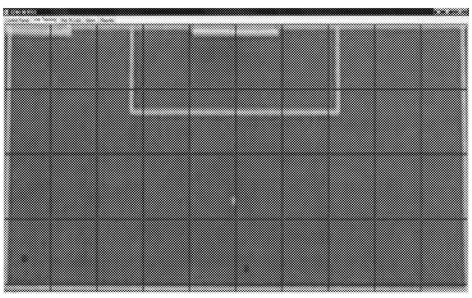

Figure 9: Striker Position during a pass

Overall the system remained stable during the whole training session thus confirming its robustness and applicability as a tool for scientific soccer analysis.

CONCLUSION AND FUTURE WORK

In this section, the project's main conclusions shall be presented as well as major future work areas and potential collateral applications are deputed. In this paper a new tracking system tested in a penalty box area in the universe of soccer is presented. As mentioned in section 3, with the construction of a portable and inexpensive system that includes basic wireless network, a car battery and UPS it was possible to track players on a real time basis all over a penalty box in a soccer field. This project shows that a Wi-Fi based technology could constitute an excellent solution for soccer. Unlike other location systems in this approach the occlusion problems are reduced to a residual level, the signal's strength al does not degenerate over the period of the training session and the accuracy levels are quite satisfactory- in average less than 3 meters- using low brand equipments- router and access points. With this inexpensive tracking solution any team's coach have detailed reports about the performance of a specific player or the all team in a training session or even in a soccer mach. The possibility of having real time player positions in a specific situation and historical player paths constitutes an important tactical indicator for any soccer coach. In this particular item the Oracle's Apex Technology proved to be a solid solution. It allows multiple simultaneous accesses and, consequently, dramatically enhancer analysis empowerment, while, at the same time, eliminates heavy data computation from end-users terminals. These characteristics allow accesses from unconventional systems such as PDAs, smartphones and not only notebooks and desktop computers through their web-based interface. This particular feature has a great importance for, technical staff that for instance is spread through the soccer stadium in a match. Regarding future work areas there are many possibilities that could wide potential the robustness and reliability of this system and new applications. Concerning to the positioning engine; the algorithm of tracking could be improved. This particularly point merged with the use of better wireless equipment will increase the accuracy of the system. Secondly, another item that could be always improved is the tag dimension. After this optimization it will be possible to incorporate this type of tags in a player's shirt without any risks for physical integrity. Another feature that could be interesting to explore as future work is the transformation of the actual system in a complete support decision framework for soccer coaches. For that purpose it is necessary to build a hybrid tracking system made by two synchronous modules. One module will be responsible for tracking the players and for this the actual system could be a solution and the other one should be responsible for tracking the ball. In this last problem one of two solutions could be adopted: a camera based classic solution with the advantage of only needing to track a specific object (with particular dimensions and color) decreasing so, the occlusion problems or adopt a new type of approach using, for instance, a chip inside the ball.

The second step for this new system will be the construction of soccer ontology. This point has particular importance because it helps to define concepts relationship with events of the game like: a pass, a shot, a corner etc. After that it is possible to construct a tracking system that will be capable to automatically detect game events, calculate historical player paths and in an advance face automatically detect player behavior relationship not only with their positioning but also with ball's. This system will definitely fill a gap in the market. Taking into account the current project's features and also the identified future enhancements, there have been identified several application domains that go beyond the soccer or even CSG. Amongst these, one shall mention the possible system's adoption by large warehouse management where traffic jams are not unusual. The proposed system would permit live vehicle tracking that in conjunction with a planning module would enable efficient traffic control, therefore avoiding bottlenecks, without compromising warehouse storage capacity. Another possible application would reside in health care institutions where it would be useful for medical staff tracking around the facilities, in order to efficiently contact them in case of emergency. Also within this domain, especially in mental institutions, patient tracking could be a great advantage. Security applications are also easy to imagine, not only to track assets in a closed environment but also potential human targets such as children in public areas – such as malls hotels or conventional centers.

As a summary, it is fair to state that the project's initial ambitions were fully met and that the cooperation with an important university in the sports area was extremely important for better measuring the system's positive impact. The technology's transparency, allied with the future work areas, is believed to greatly improve potential applications, thus significantly widening the project's initial horizons.

REFERENCES

Assfalg et al. 2003. "Semantic annotation of soccer vídeos: Automatic highlights identification." *Computer Vision, Graphics and Image understanding*, 287-310.

Baillie, M. and M. Jose. 2003. "Audio-based Event Detection for Sports Video." *CIVR2003*, 300-310.

Bayer, C. 1994. "L'Enseignement des Jeux Sportifs Collectifs.", *Éditions Vigot, Paris 1994*, ISBN: 972-576-086-7

Black et al. 2002. "Multi view image surveillance and tracking.", *Proc IEEE Workshop on Motion and Video Computing*,169-174.

Cai, Q. and J. Aggarwal. 1996. "Tracking human motion using multiple cameras.", *Proc. ICPR*, 68-72.

C et al. 2007. "Determining technology trends and forecasts of RFID by a historical review and bibliometric analysis from 1991 to 2005.", *In Technovation27*, Elvisier Ltd, 268-279.

Dobler et al. 1989. "Grundbegriffe er Sportspielle.",. Berlim: Ed. Sportvelag.

Ekin et al. 2003. "Automatic soccer video analysis and summarization.", *IEEE Trans. On Image Processing*, Vol. 12, No. 8, 796-807.

Gong et al. 1995, "Automatic parsing of TV soccer programs.", *IEEE International Conference on Multimedia Computing and Systems*, 167-174.

Hughes et al. 2001. "Establishing normative profiles in performance analysis.", *Journ. Performance Analysis of Sport*, 4-27.

Hughes, M. and R. Bartlett. 2002. "The use of performance indicators in performance analysis.", *Jornal of Sports Sciences*,739-754.

Jappinen, P. and P. J. 2007. "Preference-aware ubiquitous advertisement screen.", *In e-commerce 2007 Proceedings, IADIS Press*, 99–105.

Javed et al. 2003. "Tracking across multiple cameras with disjoint views.", *IEEE International Conference on Computer Vision (ICCV*, 952–957.

Kettnaker, V. and R. Zabih. 1999. "Bayesian multi-camera surveillance.", *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 117–123.

Khan et al. 2001. "Human tracking in multiple cameras.", *ICCV*.

Lames, M. and G. Hansen. 2001. "Designing Observational Systems to Support Top-Level Teams in Game Sports.", *J. Performance Analysis*, Vol. 1, No. 1, 85-91.

Mingkhwan, A. 2006. "Wi-fi tracker: An organization wi- fi tracking system.", *IEEE CCECE/CCGEI*, Ottawa, 1353-1356.

Naphade et al. 1998. "Probabilistic multimedia objects (MULTIJECTS): a novel approach to video indexing and retrieval in multimedia system.", *Proceedings of IEEE Conference on Image Processing*.

Nejikovsky et al. 2005. "Real time monitoring of vehicle/track interaction.", *Rail Transportation*, 25–31.

Qian, R. and V. Tovinkere. 2001. "Detecting semantic events in soccer games: Towards a complete solution.", *IEEE International Conference on Multimedia and Expo*.

Raizer, V. 2003. "Validation of two-dimensional microwave signatures.", *Geoscience and Remote Sensing Symposium, 2003*, 2694–2696.

Read, B. and P. Edwards. 1992. "Teaching Children to Play Games",Leeds:White Publishing.

Ren, R. and J. Jose. 2005. "Football Video Segmentation Based on Video Production Strategy.", *ECIR 2005*, 433-446.

Stein, G. 1998. "Tracking from multiple view points: self-calibration of space and time.", *Proc. DARPA IU Workshop*, 1037-1042.

Tsai, R. 1986. "An efficient and accurate camera calibration technique for 3D machine vision.", *Proc. CVPR*, 323-344.

Xie et al. 2004. "Structure analysis of soccer video with domain knowledge and hidden Markov models.", *Pattern Recognition Letters*, Vol. 25, Ise. 7, 767-775.

Xu et al. 2001. "Algorithms and Systems for Segmentation and Structure Analysis in Soccer Video.", *IEEE International Conference on Multimedia and Expo*.

Xu et al. 2004. "Tracking Football Players with Multiple Cameras.", *ICIP '04. 2004 International Conference on Image Processing*, Vol. 5, 2909-2912.

Yow et al. 1995. "Analysis and presentation of soccer highlights from digital video.", *In Asian Conference on Computer Vision*.

Yu, Z. 2005. "GPS train location and error analysis which based on the track fitting of the railway's geometric locus.", *ICEMI 2005: Conference Proceedings of the Seventh International Conference on Electronic Measurement*.

football history. 2008. "Football History,The story of the beautiful game.", *the oficial web site, http://www.football-history.net/historic-overview.htm.*.

BUSINESS AND PRODUCT DEVELOPMENT

A DESCRIPTION OF SEMI-AUTOMATIC CREATION OF REQUIREMENTS SPECIFICATION FROM BUSINESS ACTIVITIES

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KEYWORDS
Business Modeling, Business Process, Requirements Specification, Use Case, HDA, Higher Dimensional Automata

ABSTRACT

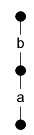
In this paper, we present a usage of our method for semi-automatic creation of requirement specification from business activities based on a real example. Activities that are performed in the company are analyzed and a table of activities with input and output entities is created. Next, the business processes are created from this table. Then, the business processes are transformed to the requirement specification represented by the use case model.

INTRODUCTION

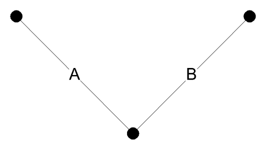
One of the main purposes of our work is to propose that the realization of the idea "create business processes and transform business processes to the requirement specification" might be very useful in the first phase of the software development process. The first phase of most development processes is often the business modeling. According to our experience, observations and discussions with the analysts and developers of the software systems of the business process phase is not often considered very useful. In fact, it is often skipped or made without proper formality. Especially, the developers of the small projects usually gather the requirements to the software system directly and do not consider the whole system as a part of the company strategy. Successful software systems should not be only a tool for the users, but it should be the strategic advantage for the managers and owners of the company, that use the software system to cover their specific needs.
The goal of our work is to find a solution to this problem, route and bridge over the business modeling and software development. There are many ways to use the business process model for software development, but we are especially concerned with the process of transformation from the business process model to the use case model (Laguan and Marklund, 2004; Penker and Eriksson, 2000; Thayler and Christensen, 2005).
Such a transformation might then be more than useful during the initial discussions between the domain specialists and system analysts to discover the scope and impact of the software system to the customer's company. A company's materials about the business processes, especially the dynamic part of it, can be used as a cross point between the scope of the company strategy and the software requirements specification (Dijkman and Joosten, 2002a; Dijkman and Joosten, 2002b; Rodríguez et al. 2007; Štolfa and Vondrák, 2004a; Štolfa and Vondrák, 2004b; Jonkers et al. 2007). The verification and validation of the requirements model can be then supported by the (semi-)formally defined connection between the business process and requirements phases of the software development.
In the following pages, it will be shown that business processes may also be useful for mapping between business process models and use case models. The next sections briefly outline the semi-automated creation of the specific business process from the activities and entities that are performed in the company and should be supported by a new system. This will be followed by an explanation of principles of mapping between business process and a use case model. The final section will discuss the conclusions and future work.

HIGHER DIMENSIONAL AUTOMATA NOTATION

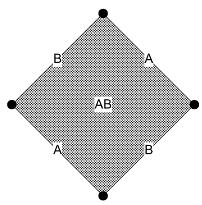
Since the HDA is used for the creation of business processes, the notation of the HDA has to be presented.



Figures 1: Sequential composition of activity A and B



Figures 2:Choice between activities A and B



Figures 3: Parallel composition of activities A and B

Basically, HDA describes activities as the edge between two states of regular finite automata. Therefore sequential

composition of two activities and the choice between two activities are clearly understandable (Fig 1 and 2). Concurrent activities are modeled as a filled square that describes true concurrency of activities (Fig 3). Detailed notation of HDA for the business processes is described in (Ježek and Vondrák, 2004).
Other notations that are used in this method – activity and use case diagrams – are more common and are not described here.

BUSINESS PROCESS CONSTRUCTION

A algorithm for semi-automated construction of business process consists of three steps. First of all, input data has to be collected. The algorithm requires list of activities and their input and output entities. That data can be easily obtained from participants of real business processes. Our example process consists of the following activities:

a_1: Creation of admission exam info
- inputs: none
- outputs: Admission exam info

a_2: Edit study info
- inputs: none
- outputs: Study info

a_3: Publish info
- inputs: Admission exam info, Study info
- outputs: Published info on WEB, Prefilled application form

a_4: Fill in application form
- inputs: Prefilled application form
- outputs: Filled application form

a_5: Check application form
- inputs: Filled application form
- outputs: Decision 1 scenario A, Decision 1 scenario B

a_6: Edit application form
- inputs: Informative e-mail
- outputs: Filled application form

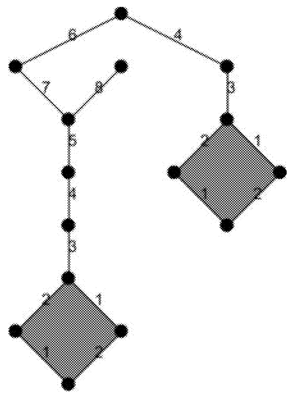
a_7: Inform applicant
- inputs: Application form with errors
- outputs: Informative e-mail

a_8: Applicant acceptance
- inputs: Application form without errors
- outputs:

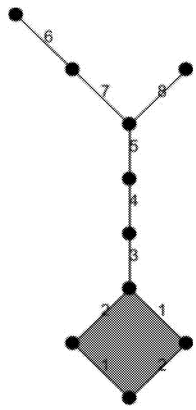
d_{1B}: Decision 1 scenario A: No errors in application form
- inputs: Decision 1 scenario A
- outputs: Application form without errors

d_{1B}: Decision 1 scenario B: Errors in application form
- inputs: Decision 1 scenario B
- outputs: Application form with errors

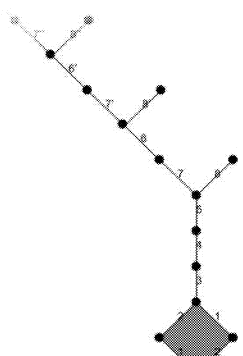
Input and output entities define a partial order of activities. Collected data are used to derive rules that determine a set of activities that have to be performed before another activity to produce entities that are consumed by this following activity. Creation of rules is described in (Vondrák et al. 2003).
All those rules have to be fulfilled for all states of searched HDA. Since all HDAs with n activities are subpart of the n dimensional cube, it is quite easy to select all parts that fulfill all rules. Each n-dimensional cube has 3^n parts. In case of a "brutal force" algorithm, it can be an unsolvable problem. Calculation time for $n > 20$ might become too long for practical use. Fortunately, business processes are not massive parallel processes and are mostly only sequential. Therefore, automaton has to find only a small number of states and a more sophisticated algorithm can be used.
The basic idea of a faster algorithm is based on the fact that all of the rules have to be satisfied (all of them are concatenated with logical AND). The algorithm starts with one rule and activities contained in that rule. Then, subparts of the n-cube that are connected to states that do not satisfy this rule are cut off. States that satisfy the rule are concatenated with future activity or activities and another rule is tested. The algorithm continues until all rules are fulfilled.
In fact, that approach works only for real processes. Theoretically, the complexity of the algorithm is still 3^n for the cases where no rule or very few of them have to be fulfilled or rules are not too restrictive. Since real business processes seems to be mostly sequential, a lot of restrictive rules are created. In cases of purely sequential processes, the complexity is n^2. Therefore, an HDA described real process is created with the complexity near to n^2.
HDA that represent the process from our example is shown on (Fig 4)



Figures 4: HDA created by automatic algorithm



Figures 5: HDA without cycle

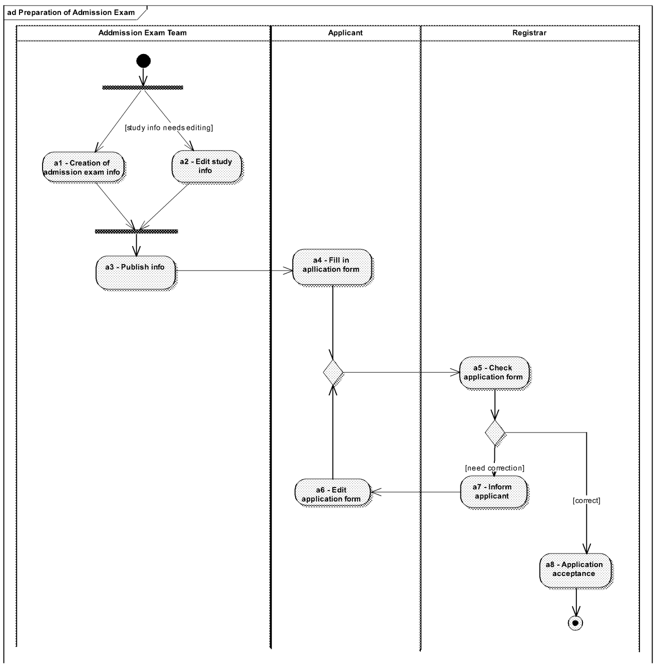


Figures 6: Mined HDA with correct cycle

HDA cannot model cycles. Since our example process contains one, the automatically created automaton (Fig 4) looks strange. There is another "start" state that contains activities that are already finished. It seems that our mining algorithm failed, but activities that are part of the cycle and the cycle start can be deducted from closer inspection of the right “bad” branch. The left branch in the connection state where “correct” and “bad” branches are connected contains activities 1, 2, 3, 4, 5, 6, 7 that are already in state DONE. “Bad” right branch contains edges for the execution of activities 1, 2, 3, 4. If we subtract them from those contained in the connection state then results show activities 5, 6, 7 that are in the cycle. Those steps can be done automatically and a result in the form of a set of activities contained in the cycle can be presented to the software engineer.

Fig 5 shows the automaton without the “bad” branch and Fig 6 shows how to describe repeatable activities by the automaton, but this presentation leads to the infinite structure in the case of an infinite number of possible iterations in the loop.

Finally, the mined automaton clearly describes the composition of activities and can be used as a skeleton for the description of the process that can be easily visualized by the UML activity diagram (Fig 7).



Figures 7: UML Activity diagram of mined process

TRANSFORMATION FROM BUSINESS PROCESS TO THE USE CASE MODEL

The basis of this part of our method is the simple mapping. Then, the pattern based mapping is built on the basis of this simple mapping. The business process role is mapped to the use case actor. This is the simplest mapping. The next mapping does not look so simple. At first, a decision about the complexity of the final use case model must be made. It depends also on the level of abstraction of the business model. If the business model is too detailed or actions could not be transformed to the use cases directly for whatever reason, then the direct mapping of the action to the use case is not the right solution. One of the solutions to this problem is the introduction of the “set concept”. “Set” is the sequence of actions that can be performed by the same role. A set is then mapped to the use case. Since the transformation method should be used for the semi-automatic or automatic generation of the use case models and should not be only another complication, sets cannot be formed completely freely. There are some constraints that should be fulfilled. The first constraint is as follows: the sequence of actions is not interrupted. The interruption is a control flow to the partition (responsibility) of the other role, some sort of delay etc. The next constraint is related to the structuring of use cases. Sets are mapped to the use cases that could be structured by include or extend relation. According to the semantics of the use case structuring, a use case that is connected to the other use cases by include or extend relation (is part of that use case or extends it) can be considered part of the original use case. It is even possible to describe all the behavior in the scenario of one big use case. Thus, the sets that are the origin of use cases cannot contain the same actions unless the intersection of these sets is one of these sets or the sets contain different occurrences of the same actions.

So, simple mapping of the sets and related concepts is as follows: Base sets (sets that are not parts of other sets) are mapped to the base use cases. Other sets that are parts of some base sets are mapped to the other use cases according to the situations described above. Relations between the base use cases and other use cases and between normal use cases are the matter of the branching and other symbols mapping. Relation between the base set and role is mapped to the relation between the actor and base use case. The action that is not equal to the set is mapped to the scenario interaction. Control flow between the actions that are included in the same set is mapped to the ordering between the interactions in the same use case. Thus, the original diagram that describes the set of actions is the description of the use case scenario. The control flow condition is mapped to the condition of the next interaction.

Mapping of the branching and other aspects of the business process is more difficult and is a matter of the pattern mapping.

Table 1: Simple mapping from the business process diagram to the use case diagram

Business Process Concept	Use Case Concept
Role	Actor
Set	Use Case
BaseSet	Base Use Case
Association between Role and BaseSet	Association between Actor and Base Use Case
Action	Interaction
Action in a Set	Interaction in a Use Case
Transition between Actions in the same Set	Ordering between Interactions in the same Use Case
Guard on transition	Constraint on interaction
Alternative Path inside atomic Set	Alternative Path description of a Use Case

Several basic mapping patterns have been developed to structure use cases according to the context of the original activities. Activities and selected parts of business processes are transformed to use cases and structured by mapping patterns.

Four main mapping patterns are used to organize use cases derived from the activity diagram to the use case diagram.

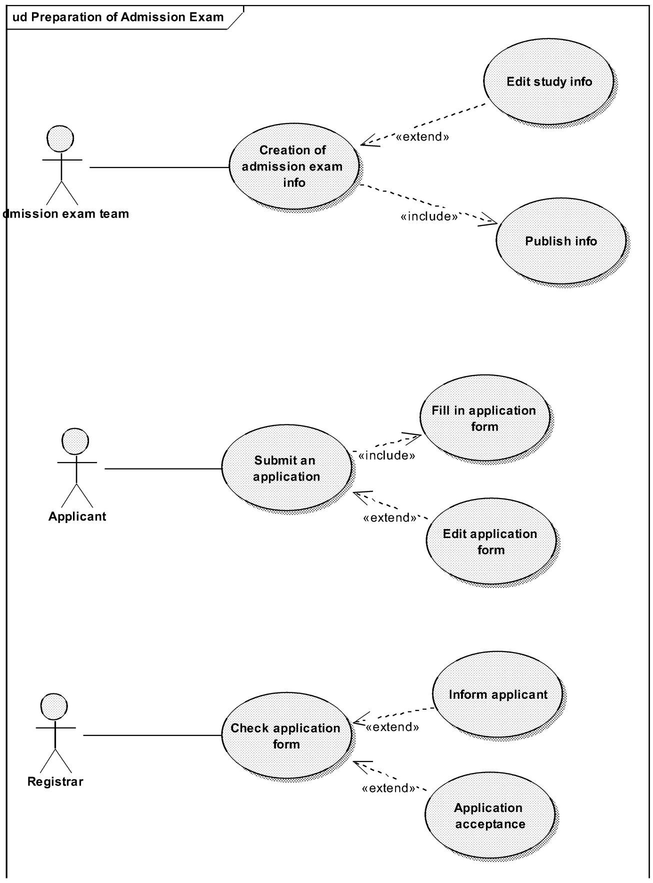
Activity diagrams of these four patterns represent basic elements that may be composed together to create a complex business process. It means that actions in patterns may be replaced by diagrams of other patterns. In fact, an automatic transformation process recognizes patterns backwards and recursively from activity diagrams. The four patterns are Sequential, Optional, Branching and Parallel.
Since the basic and pattern mappings should be clear now, the transformation procedure can be introduced. The transformation procedure consists of several steps. Each step describes a main separate transformation guide that must be applied for the successful completion of the whole transformation from the business process model to the use case requirements model.

- The first step of the transformation procedure is transformation of the roles to actors. The business process must be thoroughly inspected and the roles that are responsible for the actions that will be transformed to the use cases must be identified.
- The second step is the creation of the base sets.
- The third step is the transformation of the base sets to the base use cases.
- The fourth step is the creation of the sets that are parts of the basic sets.
- The fifth step is the transformation of the previously created sets to the use cases. The transformation is made by the pattern mapping. Mapping of the sets is recursive, which means that the first of all the basic sets are considered as the sets that enclose the whole pattern and the direct subsets are mapped to the use cases according to the appropriate patterns.

The result of all transformation steps is the final use case diagram that is structured by includes and extends relations (Fig 8) (Štolfa and Vondrák, 2004; Štolfa and Vondrák, 2004).

SUMMARY AND CONCLUSION

In this paper, we presented a newly developed approach for the requirements gathering based on the business process model. The main goal of our idea is the completely automated process of the software creation and reconfiguration. The software will be built on the base of thoroughly discussed process models. The method was developed and tested on three commercial projects. The first project contains approximately 150 individual use cases, the second project contains approximately 80 individual use cases and the third project contains about 350 individual use cases and the number is still growing, because the last two mentioned projects are still under development. The example that is used in this paper is a tiny part of the third project. Since the method was developed during the development of these projects, not all of the use cases were recognized by this method only. The classic approach was used as well and both approaches were more or less compared. The main advantage of the presented method in the practical use was the usage of the business process as a communication language between the customers and analysts.
Although the method seems to be very useful even as a semiformal or intuitive approach for the use case recognition, further use case studies are needed to continuously develop and enhance the method and support its inclusion into the software process methodologies.



Figures 8: Generated use cases for the preparation of admission exam process

REFERENCES

Dijkman, R., & Joosten, S. (November 2002). *An Algorithm to Derive Use Cases from Business Processes.* Proceedings of the 6th International Conference on Software Engineering and Applications (SEA). IASTED.
Dijkman, R., & Joosten, S. (2002). *Deriving use case diagrams from business process models.* Enschede, The Netherlands: Technical Report 02-08. CTIT.
Ježek, D., & Vondrák, I. (2004). *HDA and Resource Modeling in Business Process.* Ghent: ECEC 2004.
Jonkers, H., Steen, M. W., Heerink, L., Leeuwen, v., & Diederik. *Bridging BPM and MDE: On the Integration of BiZZdesigner and OptimalJ.* Eclipse Summit Europe 2007.
Laguan, M., & Marklund, J. (2004). *Business Process Modeling, Simulation and Design* . Prentice Hall.
Penker, M., & Eriksson, H.-E. (2000). *Business Modeling With UML: Business Patterns at Work.* Wiley.
Rodríguez, A., Fernández-Medina, E., & Piattini, M. (2007). *Using QVT to obtain Use Cases from Secure Business Processes modeled with BPMN.* Trondheim, Norway: 8th Workshop on Business Process Modeling, Development and Support.
Štolfa, S., & Vondrák, I. (2004). *An Explanation of Automatized Transformation Procedure from Business Processes to Use Case Diagrams.* Rožnov pod Radhoštěm: ISIM'04.
Štolfa, S., & Vondrák, I. (2004). *Using Business Modeling Methods for Requirements Specification.* Orlando, Fl: SCI 2004.
Thayler, R. H., & Christensen, M. J. (2005). *Software Engineering : The Development Process. 3rd edition.* IEEE Computer Society.

Vondrák, I., Ježek, D., & Snášel, V. (2003). *Automated Construction of Model of Concurrency in Business Process Modeling.* ECEC 2003.

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TRANSFORMATION MANAGEMENT OF INTERDISCIPLINARY PRODUCT LIFECYCLE MODELLING AND APPLICATION IN ICT AND VR ENVIRONMENTS

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KEYWORDS
Transformation management, product lifecycle management

ABSTRACT

The complexities and dynamics in the development and change of products and processes in industries and in related service fields are extremely rising. Therefore became necessary to master those complexities and to get control of the changes. Transformation management is the latest approach being able to manage dynamic changes in the business processes and organisations. It could be used to control the challenging development of integrated systems, characterised by interdisciplinary models and applications, in Product Lifecycle Management (PLM). The main research issue was in the creation of a multilevel conception, supported by an appropriate hardware and software infrastructure linked with a user-friendly Virtual Reality (VR) based application layer, for the first stages of the product lifecycle. The task was carried out by several industrial R&D projects. A concept of a multilevel and modular-design system for ICT infrastructures, an integrated, interdisciplinary PLM system, and a cross-disciplinary, multivalent VR environment have been created, tested and validated via utilising a pilot system, which is still extended step by step. The success of the project development is based on the appropriate use of the transformation management principles for the process changes as well as the knowledge transfer. The results are applied inside and outside the university by special R&D and user groups of industrial partners.

THE SPECIAL METHOD – TRANSFORMATION MANAGEMENT APPROACH

The term ‘transformation management’ consists of the two words ‘transformation’, bundling issues like transmutation, conversion, transfiguration, redesign, reshaping and remodelling, and ‘management’, as a combination of administration, guidance, steering and/or controlling. Therefore, transformation management is more than simply a developing concept, a management task, or a transformation process. It is the consistent and professional design of changes in the three dimensions of strategy, culture, and structure. Transformation management provides an activity guide in order to promote the participation of the potential users. It also permits open and transparent communication to initiate the willingness for change, enabling essential transformations in the organisation. The long-term aim is to create a culture of change. (Heine 2007)

The concern of the new PLM approach, based on transformation management, is to control the complexity of integrated PLM solutions, to create a reusable concept of PLM solution modelling, to improve the quality of the R&D results, to come closer to reality in PLM applications, and to increase sustainability via multiple usages of existing modules for large-scale facilities. Transformation management was selected, as philosophy, strategy, and concept, for the cooperation of the different R&D groups (related to distinct applications of specific parts in the PLM environment) working along the product lifecycle.

The new main PLM processes are developed, documented and applied by a central team of business informatics specialists, design engineers, and professional technologists. Embedding of PLM core concepts and applications in an engineering environment, to support the extended use of the available methods, tools, and facilities for related engineering and business tasks, was the issue. Especially, the ICT-based R&D fields of marketing, customer relationship management, business and information management, process, product, and job design, mechanical and electrical engineering, and ergonomics were joining together in an interdisciplinary manner.

The transformation management is organised into special stage models, used in different kinds of development processes such as systems and software engineering or project management. Typical stage models for transformation management are divided into stages as awakening, vision development, and restructuring (Tichy 1995) or awareness, confusion, strategic vision, and experimentation (Lorsch 1986) or simplification, integration, and regeneration (Ghoshal and Bartlett 1996). The concept due to Vahs (1997) is an integrated attempt consisting of two levels: a factual layer and a psychological layer. (Figure 1)

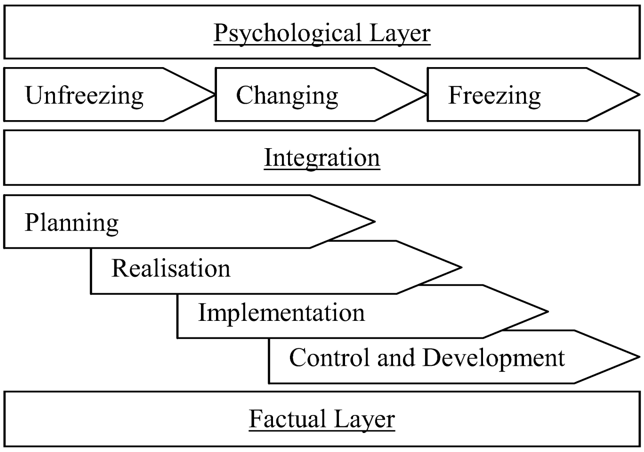

Figure 1: Integration Model of Transformation Management (Vahs 1997)

The stages of the factual layer are similar to the stage models of the project management. They are combining planning, realisation, implementation, and controlling/further development. The psychological layer includes the stages of unfreezing, changing, and freezing. The integration of psychological and factual view correlates with the transformation management idea: (Heine 2007)

(1) The activity patterns for planning and realisation need to be open up through unfreezing in order to develop the willingness for the change.
(2) The transition from the realisation to the implementation will be characterised by the change. The scale of change will be determined by the transformation processes from realisation to implementation.
(3) The completion of the implementation is supplemented by controlling and further development. It is realised on the psychological side via freezing, as fixing of the new state-of-the-art.

The motivation and the chance for change were given by the PLM affinity of the representatives of the involved R&D fields as well as the necessity to be able to control and improve the presentation, communication, and decision procedures within the internal (partners) and external (users) cooperative efforts by using the latest ICT means such as VR.

THE CORE SUBJECT – INTERDISCIPLINARY PROCESSES OF THE PLM

The engineering lifecycle of modern products as complex objects begins with the product design followed by the product shop fabrication, the product distribution and sales, discharging into the product use, maintenance, and disposal. It could be described as a unidirectional, sectional procedure with several related partners as a classic supply chain and is defined as PLM. (Schumann and Rutsch 2008) PLM is one of the most essential strategies of the enterprise information technology for the common development, administration, communication, and utilisation of product-related data in real-time for corporate divisions within companies, the cooperation partners or the customers, respectively. A large number of IT systems including product data management as the core system are applied for the realisation of the strategy. Therefore, PLM is both a holistic management concept for data management, including information deployment, and an integrated platform concept for several IT systems. (Figure 2)
But there is an essential reverse loop about processes concerning the client-specific market demand, especially in business processes based on e-business information systems. Those are directed upstream to the functions, sub-processes, and information systems of the Enterprise Resource Planning (ERP) including manufacturing, the part management, and the product development domains. The general solution is in modelling a bidirectional market-driven process flow characterised by downstream and upstream information chains in the product lifecycle permanently using control loops.

The systemic approach is based on the modelling of complex and dynamic processes of change and transformation. It has

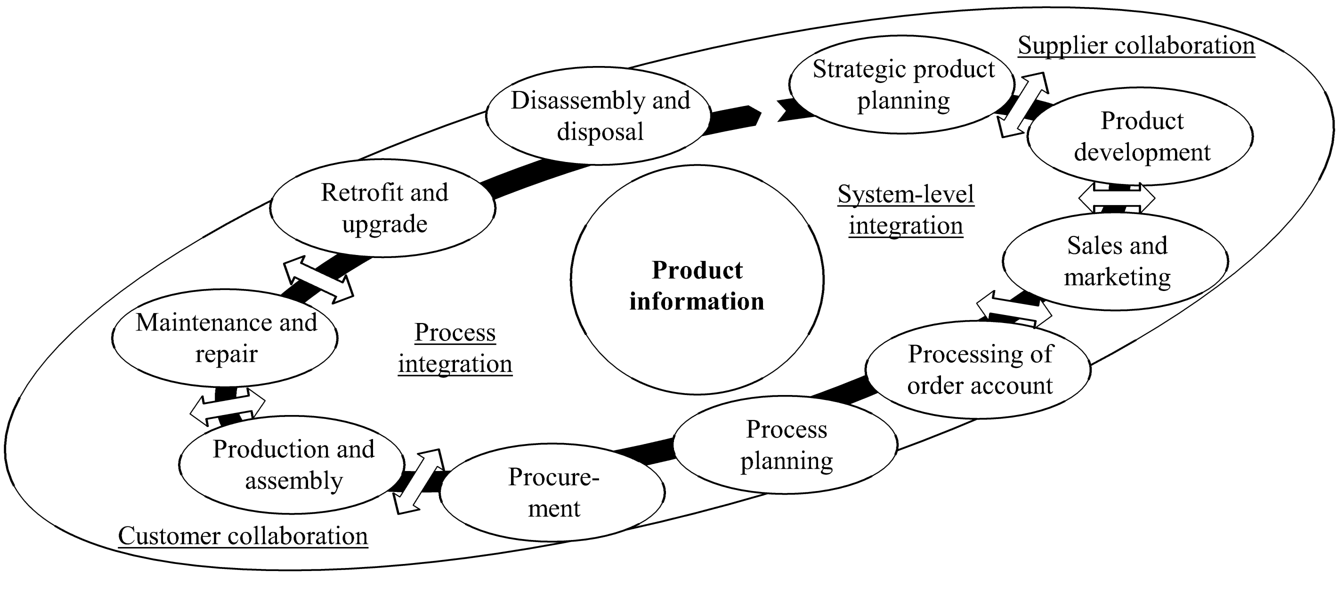

Figure 2: PLM – Product Lifecycle Management (Gröpper 2008)

to consider important aspects in addition: (Schumann and Rutsch 2008)

- Multiple human-beings create value in the product life cycle. This means, that service processes and supporting systems have to promote collaborative and interdisciplinary work.
- The general bidirectional process chain will be overlaid with local control loops in cascading process sequences. This is the precondition for generating quality in the PLM brought into line with the main rules of systems engineering management.
- The overall model will be a multilayer network approach consisting of nodes and links in the collaborative working layer, the multifunctional process layer, and the integrated information system and data layer.

Therefore, it is necessary to describe the challenging market conditions, to define the restrictions for the collaborative and interdisciplinary work, to model the processes and the network dependencies, and to create the integrated information system and product data model base line for the bidirectional information flow. Beginning with the product design and leading to the market access of the product results in an extended approach for the job scheduling and design as well as in higher process transparency, integration, and efficiency of the information system's architecture for the product lifecycle. The complicatedness and complexity, resulting from the interdisciplinary character of the holistic as well as integrated approach, requires solving the problem not only by applying different kinds of IT technologies but rather by using the methods of transformation management.

THE NEW CONCEPT – TRANSFORMATION MODELLING FOR EMBEDDED PLM PROCESSES

The new concept for PLM process application in relation to transformation management correlates with the methods of modern system's design. It needs to be systemic, modular, and cross-linked. For those reasons, it makes sense to use the facilities of layers in a multi-tier architecture for the gross planning. Layer modelling is a frequently applied principle of system's structuring. The different aspects of the system will be allocated to and arranged in the frame of one related layer. Due to the dependency inversion principle of the object-oriented design, the access from one to another layer is only allowed to the upper and to the layer below. In our case, the aspects are cross-linked functions or classes of functions needed to achieve the objectives of the layer.

The general frame model of transformation management for complex ICT applications can be divided into four layers including interdisciplinary cooperation, presentation and access, application modelling and processing, and ICT infrastructure and system.

The interdisciplinary cooperation frame is mostly related to the key issue of the transformation management as a dialectical entity of psychological and factual aspects for the increasing change efforts in organisations. It is the layer for enabling the interdisciplinary cooperation of different scientific domains and specialists in networks of development and application.

The presentation and access frame controls and manages the access of the users to the logical and physical frames of the system. It provides a user-friendly presentation of the system's information, the user-system communication and interaction as the human-system interface.

The application modelling and process frame supports the logical modelling of the applications or parts of them and the control of the processing of applications in chronological and logical sequences. The two main aspects here are the application logic and the processing methods.

The basic layer of ICT infrastructure includes the connected hard and software components for data and information processing, storage, and communication as well as the engineering and building facilities. It is the foundation for the functions and processes in the factual layer of the transformation management to be realised by the higher frames of the system.

The general frame model can be translated into a specific frame model for the PLM. (Figure 3)

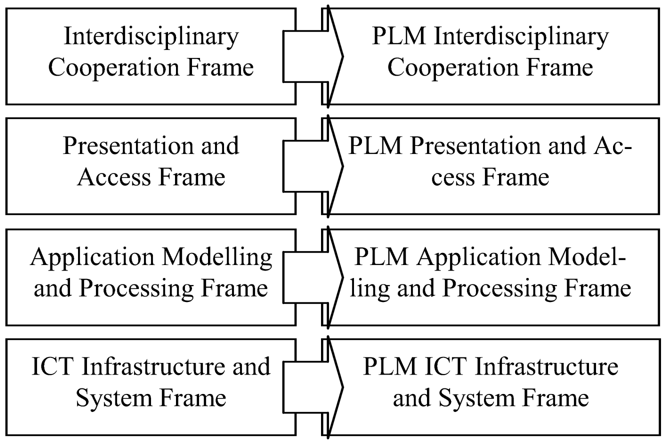

Figure 3: Frame Model and its Transformation from general ICT to PLM Application

As a result of initiating the transformation from general to specific, the four frames are getting typical item references in consideration to the special models, methods, processes, functions, and issues of the PLM.

The general ICT frame model and the specific PLM frame model are reference models, which are characterised by universal patterns for one class of aspects. They are used to derive special issues and to compare different models of the same class. The reference model, as a design pattern, is the state-of-the-art for a class of issues. The advantages of using the reference models are in better modularisation, reusability, comparability, transparency, and cost efficiency of systems and subsystems or classes of them.

The first task is to define typical PLM processes and their changes in order to be able to describe the interdisciplinary cooperation of specialists related to the PLM subjects.

The second task is to specify the content of the presentation and the user access. It focused on the application of VR and specific clients as users with respect to the state-of-the-art in PLM.

The third task is in explaining the objectives of the application modelling and process frame, as an internal transformation layer, including the complex PLM modelling and its permanent change as part of the system's transformation.

The forth task is to model the ICT base line, to select an adequate ICT equipment, and to combine the tools to a modular-design system leading to a PLM infrastructure. (Figure 4)

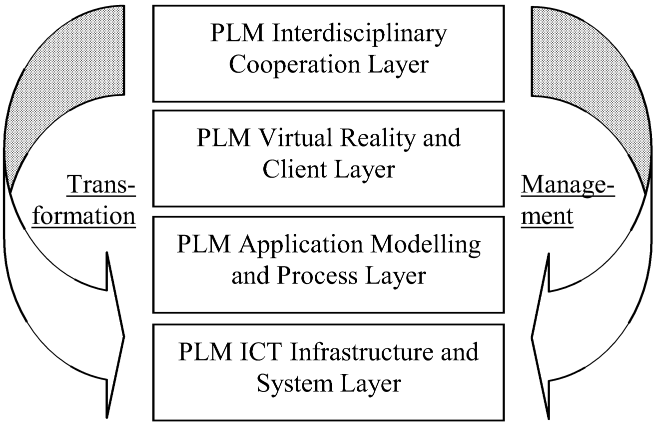

Figure 4: Model of the Pilot PLM System created with Transformation Management

As a whole, the four layers are used for collaboration in specific PLM applications and should effect changes in the PLM loops, continuously requiring the participation of transformation management.

THE REALISATION – IMPLEMENTATION OF A SCALABLE PILOT SYSTEM

The creation of a pilot system at the University of Applied Sciences Zwickau was much more than a plain PLM laboratory design. One of the further detailed approaches for stage modelling in transformation management, the concept due to Kotter (1996), was applied to realise a scalable pilot system for the regional development of PLM. This approach includes eight steps (Kotter 1996) backed up by specific activities for the individual solution. (Table 1)

Table 1: The Transformation Management Phases for a PLM Pilot System

(Step) Specification	Project Transformation
(1) Establishing a Sense of Urgency	The understanding of product development and product-to-market relations as competitive factors requires changes in research and study programs.
(2) Creating the Guiding Coalition	The PLM user group was founded as a team of representatives from PLM service and application companies, research organisations, and educational institutes.
(3) Developing a Vision and Strategy	A common vision and a strategy for teaching and applying of PLM were developed. They were discussed and improved in several workshops and on an international conference.
(4) Communicating the Change Vision	The change vision and mission was constantly discussed and communicated in the educational and research processes inside and outside the university.
(5) Empowering Broad-Based Action	The psychological, mental, factual, personal, and constructional preconditions were formed by an increasing number of skilled team members.
(6) Generating Short-term Wins	Realising a research project and establishing pilot processes and systems for the PLM product-to-market-cycle.
(7) Consolidation Gains and Producing more Changes	The gains were immediately consolidated in the framework of transformation in the curriculum and research program. They are used to produce more changes by extending the PLM user group and improving the PLM laboratory cooperation.
(8) Anchoring new Approaches in the Culture	A new scalable pilot system as research and demonstration centre will be used for customer orientation, effective management, new group dynamic behaviour, and enhanced collaboration.

The system approach for the pilot PLM solution was developed, based upon transformation management as the corporate or moreover research project culture, in several phases of knowledge enrichment and model adjustment. The complex PLM transformation model started as a simple model within a PM application in a SME (Schumann et al. 2007), changed to a functional PLM environment in a research project (Rutsch and Schumann 2008) as well as to a complex

PLM network system architecture, and was finally topped via the introduction of a bidirectional PLM world. (Figure 5)

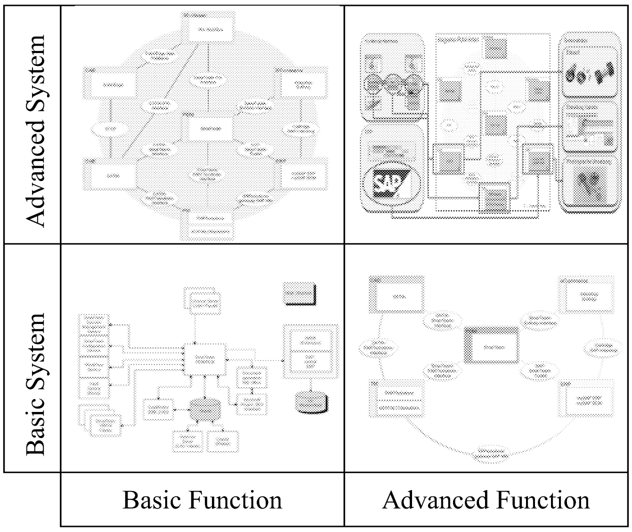

Figure 5: Model-Driven Architecture Development based on Transformation Management

The regional transformation in PLM research, education, services and application is pushed by representatives of the Institutes of Business Economics, of Management and Information, of Automotive Engineering, of Automobile Production and Engineering at the University of Applied Sciences Zwickau in cooperation with the Institutes for Industrial Management and Factory Systems as well as for Virtual Production Engineering at the Chemnitz University of Technology. It joins specialists in management, economics, informatics, plant design, marketing, ergonomics, and mechanical, automotive and production engineering cooperating in the product development, product management and product distribution cycle. All collaborating in an integrated PLM R&D centre (equipped for instance with VR tools) consisting of different kinds of sub-laboratories for marketing, ergonomics, e-business, information logistics, and engineering. (Figure 6)

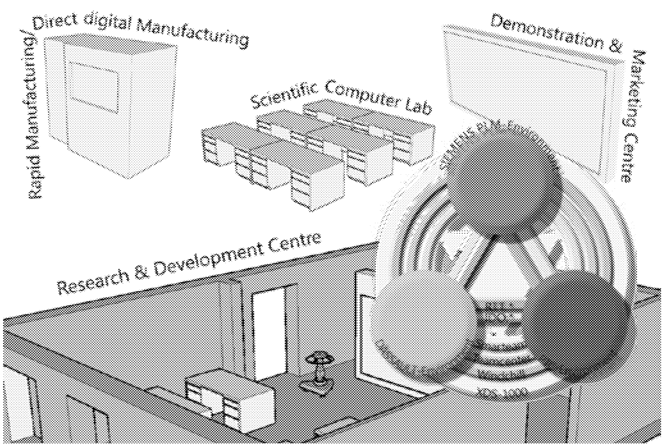

Figure 6: Interdisciplinary PLM R&D Centre as the Subject of Transformation Management

SUMMARY

Transformation management is an approach for improving the interdisciplinary cooperation in R&D as well as in education and training. It was and is used for accelerating the development of the first phase, beginning with the product design via product and product data management crossing the ERP system to the e-commerce applications, of the product lifecycle modelling and application. The system is implemented in a special PLM R&D centre in an ICT and VR environment. The project is guided in the sense of an interdisciplinary cultural approach, respecting both: psychological and factual aspects.

REFERENCES

Ghoshal, S. and C. A. Bartlett. 1996. “Rebuilding Behavioural Context : A Blueprint for Corporate Renewal.” In *Sloan Management Review*, 38(1996), 23-36.

Gröpper, M. 2008. *PLM – Product Lifecycle Management*. VDMA.

Heine, S. 2007. *Systematische Transformationssteuerung*. VDM. Saarbrücken, 27-30.

Kotter, J.P. 1996. *Leading Change*. Harvard Press. Boston, 20-23.

Lorsch, J. W. 1986. “Managing Culture : The Invisible Barrier to Strategic Change.” In: *California Management Review*, 28(1986), 95-109.

Rutsch, A. and C.-A. Schumann. 2008. “Towards an Integrated Corporate Information System: Building up a Sales Product Data Model to cope with the Emerging Complexity of e-Business.” In: Brito, A. C. and J. M. Teixeira: *Proceedings of the 15th European Concurrent Engineering Conference*. Porto, 74-78.

Schumann, C.-A.; C. Tittmann; M. Didszun et al. 2007. “Directed Access of Multichannel E-Commerce Systems to Data Sources of Integrated SME Information Systems.” In: Van Welden, D.: *Proceedings of the 14th European Concurrent Engineering Conference*. ECEC2007, Delft, 2007. 34-38.

Schumann, C.-A. and A. Rutsch. 2008. “Market Driven Merger of E-Business, Enterprise Resource, and Product Management Systems in the PLM-Loop.” In: Cunningham, P. and M. Cunningham: *Collaboration and the Knowledge Economy*. IOS Press, Amsterdam, 665-672.

Tichy, N. 1995. *Regieanweisung für Revolutionäre*. Campus Fachbuch, Frankfurt.

Vahs, D. 1997. “Unternehmenswandel und Widerstand.” In: *io management*, 66(1997), 18-24.

BIOGRAPHY

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AN APPROACH FOR A NEEDS-DRIVEN DEFINITION OF A FUNCTION-ORIENTED REPRESENTATION IN THE AUTOMOTIVE DOMAIN

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KEYWORDS
Function Orientation, Function-oriented Representation, Product Model, Automotive Electric/Electronic-systems

ABSTRACT

The importance of a function driven way of working in the field of Electric/Electronic-systems (E/E) is increasing. However, the existing methods are focusing on the development phase. But we are convinced that a function-oriented representation can also be helpful in the late phases of the product life cycle. However, the initial modeling and maintenance of information contained in a function-oriented representation of a product is associated with time and effort. In this paper we describe a method to define an adequate function-oriented representation with consideration of benefit and effort.

INTRODUCTION

Modern automobiles have a huge amount of innovations inside and are characterized by high complexity, especially concerning Electric/Electronic systems (E/E). There are many functions which are distributed over several components. At the moment, the components of an automobile are in the focus throughout the product life cycle. For example, this becomes apparent in the product documentation which is concentrated on components. Moreover, the arrangement of the organizational structure in development is influenced by components. In addition, development processes focus on components. However, this component driven way of working is not sufficient to deal with the complexity of today's automobiles.
In order to meet this challenge, there is an ongoing paradigm shift towards function orientation. Function orientation implies that the functions of an automobile are being considered explicitly, i.e. by documenting functions and including this documentation into development processes such as test planning. This way it is easier to perceive the interdependencies within a product. Moreover, functions are the most important issue of a product from the customer's point of view. By having an explicit view on functions it is possible to ensure that these functions are fulfilled at the end of the development process.
The use of functions in the early stage of the product development process has often been addressed in recent research. For example, in (Pahl et al. 2007), (Roth 2000) and (Gausemeier et al. 2008) the focus is directed to the usage of functions in order to find new product concepts and solutions. In (Warkentin et al. 2009a) we show that a function-oriented representation can also be helpful beyond the development phase, i.e. during manufacturing process planning, manufacturing and usage of a product. However, the initial modeling of information contained in a function-oriented representation of a product is associated with time and effort. In the same way, maintenance of this information throughout the product life cycle is expensive in labour. Consequently, there is a trade-off between the benefit arising from the usage of a function-oriented representation and the effort connected with modeling and updating this information. Current approaches which deal with a function-oriented representation are not concerned with this question. So, there are different approaches to represent a product in a function-oriented way but they do not answer the question which elements out of the representation have to be modeled and updated throughout the product life cycle. Therefore, our goal is to define a method to answer this question. Figure 1 shows the basic idea. We take relevant use cases to define an appropriate function-oriented representation. In this paper we describe this method in detail. It will enable us to find an optimum between the effort associated with modeling and updating of information on the one hand and the benefit associated with the usage of this information on the other hand.
The remainder of this paper is structured as follows. Section 2 illustrates a concept of a function-oriented representation. Section 3 describes a method to consider benefit and effort of modeling and updating of information within the function-oriented representation. Section 4 concludes with a summary of the main results and an outlook.

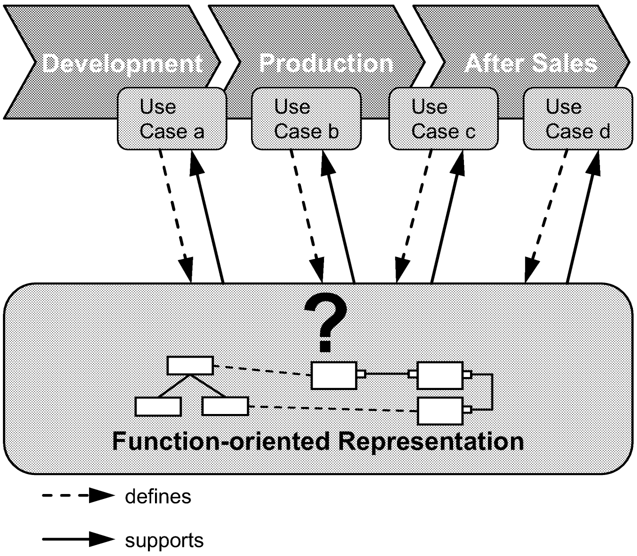

Figure 1: Definition of a function-oriented representation based on the intended utilisation

FUNCTION-ORIENTED REPRESENTATION

In this section, we describe an approach to describe automotive E/E-systems in a function-oriented way. This function-oriented representation serves as a basis for the late phases of the product lifecycle and is based, among other things, on related approaches considering functions ((Frauenhofer Institut für Software- und Systemtechnik 2006), (Ringler et al. 2007), (Politze and Dierssen 2008)).
To include the various aspects of an E/E-system, we use three levels of abstraction which are interconnected. In the first, most abstract level functions are presented as they are perceived by the user or customer respectively. This level is called **user level.** Here, functions are independent of realization details. The user-level is intended to ensure the conception, realization and validation from the user's perspective. This also includes a high-level description concerning the expected behaviour of an E/E-system. In particular, it is described how functions can be started and stopped. Moreover, conditions that have to be fulfilled before starting a function are modeled. To represent the complexity contained in an E/E-system functions are decomposed into subfunctions.
In contrast to the user level, the second level concentrates on the way the functions are realized on a logical level. This level is called **logical architecture** or design level. Here, the description of functions is more detailed. The logical architecture is intended to support the realization of the functions modeled in the user-level. It contains a decomposition of functions and information concerning the in- and output on a logical level. Functions are connected via flows between these in- and outputs. Another important issue is the description of the behaviour of a function, e.g. via a state transition process.
The third level describes the technical details of E/E-systems. Therefore, this level is called **technical architecture**. The technical architecture consists of hardware and software architecture. The hardware architecture includes the physical components of an E/E-system. Above all, these are actuators, sensors as well as control units and physical interconnections. The software architecture describes the software components of an E/E-system.
The three levels of abstraction are interconnected. Inter alia, functions and conditions of the user-level are connected with the technical functions of the logical architecture. The functions of the logical architecture are linked to hardware and software elements as well as physical components of the technical architecture.

EFFORT-BENEFIT-CONSIDERATIONS

In this section, we describe a method to define an appropriate function-oriented representation under consideration of desired solutions for use cases. Figure 2 shows the steps to be performed within this method. First of all, relevant use cases are identified and appropriate solutions are defined. Dependencies between these solutions and elements of the function-oriented representation are analyzed in the next step. Afterwards, the benefit and effort connected with the solutions and the modeling of elements is estimated and the target situation defined. Moreover, intermediate steps to reach the target situation can be defined. In the remainder of this section, we discuss these steps in detail.

Identification of Use Cases

In the first step use cases are identified. A use case in our context is a task or activity within a company in which a function-oriented representation is potentially helpful. If necessary, use cases can be prioritized. In (Warkentin et al. 2009a), we illustrate several correspondent use cases.
For each use case several solutions can be defined as there are typically several possible solutions for each use case, i.e. there are different possibilities to face the challenges identified in a use case. A use case can be handled with a rather simple function-oriented representation or with a rather sophisticated one. Thus, after defining use cases, a definition of solutions for these use cases is important.
We show this by illustrating solutions for one use case as an example. This use case deals with the prioritization of functions to be tested in manufacturing. In order to find a solution for prioritizing functions, the failure mode and effects analysis (FMEA) and the field of risk management are helpful. These approaches address a similar issue. In FMEA and risk management, the following factors are relevant: probability of a failure and consequences of a failure (NN 1980), (Pfleeger 2000), (Amland 2000). In FMEA, detectability of a failure is additionally taken into account. Thus, according to these approaches, the following influencing factors have to be taken into consideration in order to prioritize functions to be tested:

- Severity of the consequences caused by a failure in a function: This factor describes the seriousness of consequences that result from a defective function from the customer's point of view.

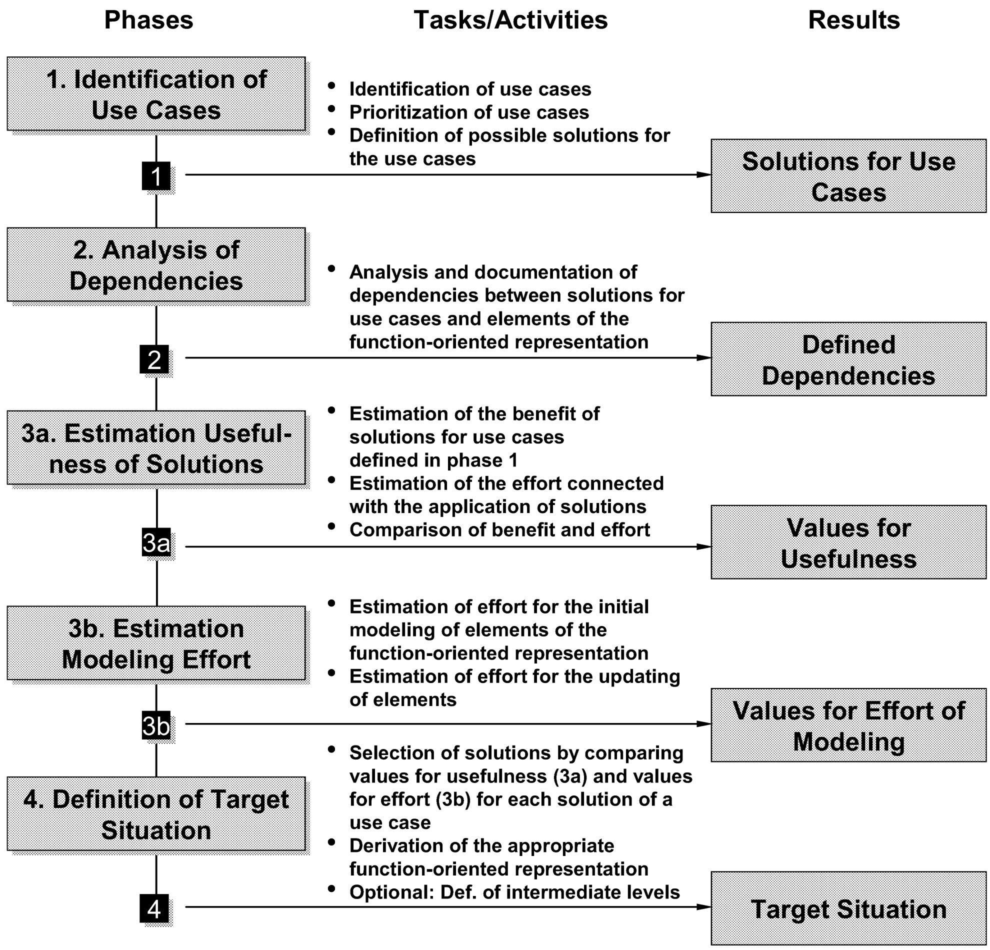

Figure 2: Method to define an appropriate function-oriented representation and solutions for use cases

- Probability of a failure in a function: This factor describes the likeliness of a failure to occur in a function.
- Probability of detecting a failure (detectability): This factor describes the likeliness to find a failure before a product arrives at the customer.

The combination of these three factors leads to the prioritization of functions to be tested.

There are several basic principles to determine values for the three factors as shown in Figure 3.

The first basic principle is to estimate values in a subjective manner on the basis of the knowledge of experts (aa) and ba) in Figure 3). Thus, it is possible to prioritize functions without a comprehensive basis of information concerning functions, e.g. information about the mapping relations between components and functions. Only a documentation of functions on the user level of an automobile is helpful for the estimation of values in a subjective manner.

Another basic principle is to determine or even calculate estimated values for severity, probability and detectability on the basis of detailed information from a function-oriented representation experts (aba) and abb) in Figure 3). The following short example for the determination of values for the probability of a failure in a function shall deliver an insight into the possible information that could be taken into consideration. A more detailed description can be found in (Warkentin et al. 2009b). For the determination of the probability of a failure it is helpful to take, among other things, the complexity and error rates of related components into consideration. Complexity can for example be estimated on the basis of the number of hardware and software components that are necessary to fulfill the considered function. Here, information like the lines of code (LOC) of participating software can give an additional hint concerning complexity of a function. Moreover, existing information regarding error rates of the components related to the considered function improves the determination of the probability of a failure. To sum it up, information about mapping relations between components and functions is important for a determination of probability of a failure in a function.

The choosing of one of these basic principles for each of the influencing factors (a), b) and c) in Figure 3) leads to one possible, concrete solution for the use case prioritization of functions. The definition of such solutions is important for the next step.

Analysis of Dependencies

After identifying use cases and corresponding solutions, dependencies between solutions and elements of function-oriented representation are analyzed. These dependencies show, which elements are necessary or at least helpful for the execution of the solutions defined in the previous step.

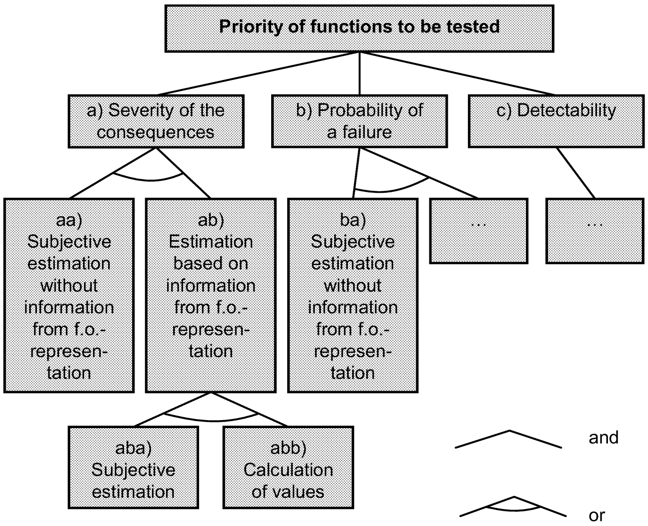

Figure 3: Basic principles for the determination of influencing factors for prioritizing functions

Figure 4 shows the basic concept. The left columns contain the use cases and the corresponding solutions. The solutions within a use case represent alternatives, i.e. the choice of one solution excludes choosing the other solutions. As an example, one solution might be the estimation of a), b) and c) in Figure 3 on the basis of information form the function-oriented representation by calculating corresponding values (abb) etc. in Figure 3). The top row contains an excerpt of elements of a function-oriented representation as mentioned in the previous section. These elements of a function-oriented representation are as described in section 2. This way, there is a statement about the required elements of the function-oriented representation for every solution.

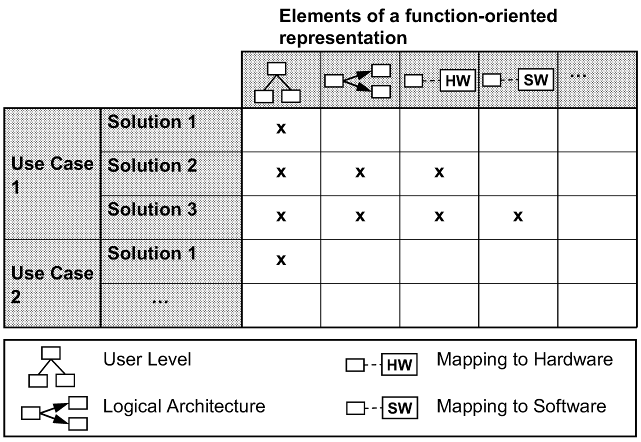

Figure 4: Dependencies between solutions of use cases and elements of a function-oriented representation

Estimation of the Usefulness of Solutions for the Use Cases

As there are several possible solutions for each use case and one of these solutions has to be chosen, values for the usefulness of these solutions have to be estimated. There are two main criteria which influence the usefulness: the benefit and the effort of a solution. Figure 5 shows these criteria in conjunction with use cases or corresponding solutions respectively and elements of the function-oriented representation. The benefit (a) of all solutions in which a certain element is helpful determines the benefit (d) of this element. Another important criterion in this step is the effort (b) for the execution of a solution.

When considering benefit, we distinguish between tangible and intangible benefits. Tangible benefits are measurable and quantifiable. These benefits are often expressed in monetary units. Here, one distinguishes between increased revenues on the one hand and decreased costs on the other hand. In contrast to this, intangible benefits are typically not quantifiable in monetary units. For example, an increase in customer satisfaction is a typical intangible benefit. To include intangible benefits into decision-making, they are expressed in terms of qualitative values gathered from subjective measures (Mutschler et al. 2007).

Besides the benefit of a solution, the effort connected to the application of this solution ((b) in Figure 5) has also to be considered. Here, we regard all activities which have to be done to execute a solution. To define this effort, two approaches are possible: direct and indirect estimation. The former quantifies the effort with values like labour time for the execution. The latter uses properties like the complexity of the execution or the needed expert know-how to derive the effort.

When defining values for benefit and effort, because of the involved subjectivity and heterogeneity a reasonable estimation is challenging.

The last sub-step is the comparison of the benefit and the effort for each solution to compare all solutions of a use case among each other. To do so, it is crucial to assign appropriate weighting factors before comparing the benefit and effort. Alternatively, the values for benefit and effort can be kept separately in order to be considered explicitly in the last step.

Estimation of Modeling Effort

The estimation of the modeling effort for the elements ((e) in Figure 5) contained in the function-oriented representation is an important step in our method. In the previous step, the focus is directed to the effort connected with the activities needed for a certain solution for a use case. In this step we concentrate on the effort caused by the modeling of elements which are necessary for the activities or solutions respectively. It consists of all costs which are attended by the initial modeling and updating of information for an element. To define modeling effort two approaches are possible: direct and indirect estimation. The former quantifies the effort directly with values like labour time for the initial modeling and updating per element. The latter uses properties of an element which influence the effort of modeling, e.g. complexity or update frequency.

Definition of Target Situation

The next step is the selection of appropriate solutions for the use cases and a derivation of the corresponding function-oriented representation.

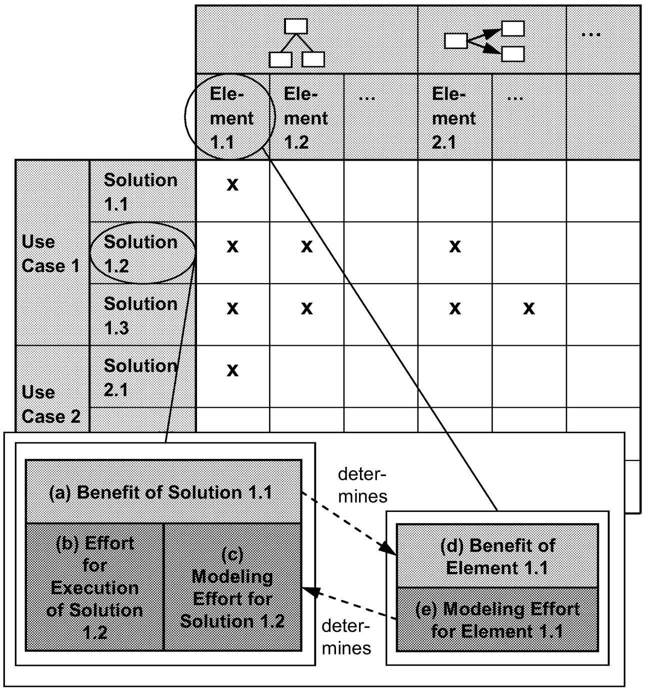

Figure 5: Benefit and effort of solutions for use cases

To do so, the efforts and benefits analyzed in the previous steps are compared to each other. We suggest two alternatives to do so. It is also possible to combine the two alternatives.

In the first alternative, appropriate solutions are defined in a subjective manner by focusing on several aspects and eliminating extrema. The goal is to identify and disregard solutions which lead to a high effort without bringing much benefit. Thus, solutions which depend on elements other solutions do not need and characterized with a high modeling effort are not taken into consideration.

The second alternative compares all possible combinations of solutions. Therefore, weighing factors are assigned to the benefit of solutions ((a) in Figure 5), to the effort of the execution of solution (b) and to the modeling effort (c). The combination with the best value for the combination of the three criteria defines the target situation.

A direct transition to the target situation defined in this step might not be manageable, e.g. if the target situation contains a rather comprehensive function-oriented representation. In this case, it is helpful to define intermediate levels concerning the solutions for use cases as well as the appropriate function-oriented representation. These intermediate levels would be successively applied. To define these levels, the values for benefit and effort from previous steps and consistency of the function-oriented representation have to be taken into consideration. The former aims at an identification of quick wins to increase the acceptance and to facilitate the application of the following levels. The latter aims at the consistency of the elements of the function-oriented representation chosen for an intermediate level. Moreover, the identification and consideration of interdependencies between the solutions is important. For example, in some use cases it might be helpful to establish a rather simple solution before introducing a more complex solution.

SUMMARY AND OUTLOOK

The so-called function orientation can generally be helpful in the development phase as well as in the late phases of the product lifecycle. For this purpose a function-oriented representation is a crucial factor. In this paper we described a method to derive such a function-oriented representation taking into account the benefit arising from the usage as well as the effort resulting from the modeling and updating of information. This method will enable us to define a function-oriented representation being suitable for our purposes.

As we illustrated in this paper, there are still some open questions left. Therefore, ongoing activities aim at answering these questions. The method described in this paper uses values based on estimation. Thus, it is likely that some of the estimations made may turn out to be incorrect during application. Thus, it is important to develop mechanisms to monitor the success during the application of the method to be able to counteract if needed.

REFERENCES

Amland, S. 2000. "Risk-based testing." *The Journal of Systems Software* 53, No. 3, 287-295.

Frauenhofer Institut für Software- und Systemtechnik. 2006. "Modellbasierte Systementwicklung in der Automobilindustrie - Das MOSES Projekt." Fraunhofer-Gesellschaft, Berlin.

Gausemeier, J.; Zimmer, D.; Donoth, J.; Pook, S. and A. Schmidt. 2008. "Proceeding for the Conceptual Design of Self-Optimizing Mechatronic Systems." In *Proceedings of the International Design Conference – DESIGN* (Dubrovnik, Croatia, May 19-22).

Mutschler, B.; Zarvic, N. and M. U. Reichert. 2007. "A Survey on Economic-driven Evaluations of Information Technology." University of Twente, Enschede.

NN. 1980. "Military Standard 1629 A. Procedures for Performing a FMECA." Department of Defense, USA.

Pahl, G.; Beitz, W.; Feldhusen, J. and K. Grote. 2007. "Engineering Design - A Systematic Approach." Springer, Berlin.

Pfleeger, S. L. 2000. "Risky business: what we have yet to learn about risk management." *The Journal of Systems Software* 53, No. 3, 265-273.

Politze, D. P. and S. Dierssen. 2008. "A Functional Model for the Function Oriented Description of Customer-related Functions of High Variant Products." In *NordDesign 2009* (Tallinn, Estonia, August 21-23).

Ringler, T.; Simons, M. and R. Beck. 2007. "Reifegradsteigerung durch methodischen Architekturentwurf mit dem E/E-Konzeptwerkzeug." In *13. Internationaler Kongress Elektronik im Kraftfahrzeug* (Baden-Baden, Germany, October 10-11). VDI Verlag, Düsseldorf.

Roth, K. 2000. "Konstruieren mit Konstruktionskatalogen." Springer, Berlin.

Warkentin, A.; Gausemeier, J. and J. Herbst. 2009a. "Function Orientation beyond Development – Use Cases in the Late Phases of the Product Life Cycle." In *CIRP Design Conference 2009* (Cranfield, UK, March 30-31).

Warkentin, A.; Herbst, J. and J. Gausemeier. 2009b. "Konzeption eines funktionsorientierten Produktmodells zur Nutzung in den nachgelagerten Phasen des Produktlebenszyklus." In *6. Paderborner Workshop Entwurf mechatronischer Systeme* (Paderborn, Germany, April 2-3).

JOINT OPTIMIZATION OF ALL INSPECTION PARAMETERS FOR MULTI-STAGE PROCESSES: ALGORITHM, SIMULATION AND TEST SET

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KEYWORDS
Evolutionary algortihm, inspection allocation, quality economics, simulation.

ABSTRACT

The problem of determining the optimal inspection strategy for a given multistage production process, i.e. an efficient inspection strategy that results in the lowest total inspection cost, is modeled as a joint optimization of all inspection parameters (inspection location, inspection type, inspection limits and sampling characteristics). To solve this problem, a metaheuristic solution approach, namely an Evolutionary Algorithm (EA), is proposed. Simulation is used to calculate the inspection costs for every candidate solution. A test set of problem instances is suggested to explore the characteristics and possibilities of the proposed EA metaheuristic.

INTRODUCTION

Efficient production quality control is a major issue to manufacturers. In manufacturing, reducing variance is the major key to achieve quality, requiring implementation of an efficient inspection strategy. Economic inspection strategies ensure the required output quality while minimizing the total inspection cost. Generally, more and tighter inspection will induce a higher product quality, but will also result in higher costs of inspection, scrap and rework. An economic inspection plan balances this trade-off.

Most processes consist of a sequence of production stages. Each stage but the last produces input for the next production stage. As the production processes at each stage are generally stochastic in nature, deviations from expected product specifications occur, which, without intervention, accumulate in the course of the production process. Quality inspection only at the last stage could therefore result in a large number of faulty products and high rework and scrap costs. Hence, performing some form "intermediate" inspection is common practice in most multi-stage processes.

An inspection strategy for a so-called serial multistage production system (MSPS) decides on:

- the number and location of inspection stations;
- the inspection limits for each inspection station;
- the sample size or sampling frequency and acceptance criteria for each inspection station.

The problem facing the MSPS inspection planner thus consists of finding the combination of these inspection parameters in order to minimize the total expected inspection cost *TIC*. This is a complex joint optimization problem. The problem of simultaneously optimizing the location of inspection stations and the associated inspection limits was addressed in Van Volsem (2006).

By embedding simulation to model the serial n-stage MSPS in an Evolutionary Algorithm (EA) to perform the actual optimization, this paper offers a joint inspection optimization method. As an EA is a metaheuristic, the solution obtained will not necessarily be the best possible solution, but the EA will enable finding a good feasible solution in an acceptable amount of time.

THE MSPS MODEL

Consider a serial MSPS in which products travel sequentially from stage 1 to stage n and inspection of products is performed by $k \leq n$ inspection stations (see Figure 1). At each stage, a manufacturing action is performed on or with the products, before moving on to an inspection station, or to the processing station of the next stage.

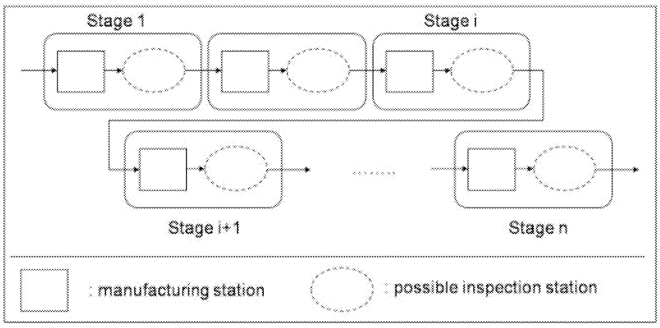


Figure 1: A Sequential MSPS

After each processing station, one of three inspection types is selected: no inspection **N**, full inspection **F**, or sampling inspection **S**. For sampling or full inspection, inspection limits subsequently have to be determined. Finally, for the sampling inspection option the sample size and acceptance number have to be determined.

We consider a constant production and inspection rate, perfect inspection and perfect rework. We consider product to be defective when the value of its quality characteristic in stage i is outside its inspection limits, i.e. outside the interval $[LIL_i\ ,UIL_i]$. For such a sequential MSPS with n process stages and a batchsize of K items, the following notations are introduced:

$p_i' \; = \;$ fault occurrence in stage i

$LIL_i \; = \;$ lower inspection limit in stage i (variable)

$UIL_i \; = \;$ upper inspection limit in stage i (variable)

$LS_n \; = \;$ lower specification limit after stage n (fixed)

$US_n \; = \;$ upper specification limit after stage n (fixed)

$s_i \; = \;$ sample size for stage i

$t_i \; = \;$ acceptance number for stage i

$d_i \; = \;$ number of bad items after stage i

$c_{T,i} \; = \;$ unit test cost in stage i

$c_{R,i} \; = \;$ unit rework cost in stage i

$c_P \; = \;$ unit penalty cost (after stage n)

$TC_i \; = \;$ test cost in stage i

$RC_i \; = \;$ rework cost in stage i

$\alpha_{F,i} \; = \;$ 1 if F is selected in stage i, $= 0$ otherwise

$\alpha_{S,i} \; = \;$ 1 if S is selected in stage i, $= 0$ otherwise

$TTC \; = \;$ total test cost

$TRC \; = \;$ total rework cost

$TPC \; = \;$ total penalty cost

$TIC \; = \;$ total inspection cost

MSPS output is defective if the value of the quality characteristic is not contained in the specification interval $[LS_n\ ,US_n]$. The fault occurrence p_i' is the fraction of defective products in stage i. Because the inspection limits are independent variables of the inspection optimization problem, the fault occurrence is a dependent variable. For a single production stage, p_i' can be calculated analytically if the distribution of the quality characteristic is known; the same holds for the first stage of a MSPS. For the following stages i (i= 2, ..., n) however, the fault occurrence not only depends on the choice of inspection limits, but also on the inspection strategy chosen in the previous stage(s). Van Volsem (2006) demonstrates that even for trivial or ostensibly simple cases, analytical calculations for p_i' become impossible and one is driven back on numerical solution methods and estimation procedures, or limited to establishing bounds. Therefore, the remaining option is to resort to (meta)heuristics.

Concerning the cost model, three types of cost are defined: test costs, rework costs, and the penalty cost.Test cost is the cost of a single test or analysis. Rework or replacement costs are incurred if a defective product is discovered through testing, and reworked or replaced by a non-defective product. The penalty cost is incurred when a defective product is shipped to the customer. Furthermore it is assumed that if a batch is rejected after acceptance sampling inspection, a full inspection of the rejected batch is performed consecutively in the same stage.

Determining the optimal inspection strategy that minimizes the *TIC*, requires the determination of inspection options α_i and the corresponding inspection limits $[LIL_i\ ,UIL_i]$ and sampling parameters $(s_i\ , t_i)$, for all stages $i = 1, ..., n$. This is what the proposed Evolutionary Algorithm does.
Determining the TIC is now straightforward:

$$TIC = TTC + TRC + TPC$$

with

$$TTC = \sum_{i=1}^{n} TC_i$$

$$TRC = \sum_{i=1}^{n} RC_i$$

$$TPC = c_P.d_n$$

and with

$$TC_i = c_{T,i}.(\alpha_{F,i}.K + \alpha_{S,i}.s_i)$$

$$RC_i = c_{R,i}.p_i'.\alpha_{F,i}.K$$

It is however clear that a completely random setting of the sampling parameters –although technically doable– would lead to pointless sampling schemes. Therefore, the variable setting of the sampling parameters is limited to a number of pre-determined combinations of $(s_i\ , t_i)$. In the algorithm, the combinations themselves, as well as the number of combinations are user-defined. As many combinations as useful can be entered, to meet process-specific demands. In the computed examples, three combinations for $(s_i\ , t_i)$ are withheld, namely (100,1), (50,1) and (25,0) - all for a constant batchsize $K = 1000$.

FINDING THE OPTIMAL INSPECTION STRATEGY

For determining the optimal inspection strategy, an Evolutionary Algorithm (EA) is presented. Evolutionary (or Genetic) Algorithms are adaptive heuristic search methods mimicking selective breeding, where offspring are sought which have certain desirable characteristics, determined at the genetic level by combination of the parents' chromosomes. In a similar way, in seeking better solutions, EA's combine pieces of existing solutions: new generations of offspring are generated through an iteration process until a convergence criterion is met. The basic concepts were developed by Holland (1975).

There are four main parts in the EA paradigm, namely the problem representation and initiation, the objective function evaluation (fitness calculation), the parent selection, and the actual evolutionary reproduction of candidate solutions.

Problem Representation and Initiation

Every proposed solution is represented by a vector of the independent variables (inspection decision variables), coded as a *chromosome* constituted by as many *genes* as the number of independent variables. In a “standard” Genetic Algorithm, binary coding is applied; the term Evolutionary Algorithm is used if other than binary encoding is applied. The chromosomes used in the EA we propose, consist of both “character” values (F, N or S), real values (LIL_i, UIL_i), and integers $(s_i\ , t_i)$.

Every candidate solution to the inspection optimization problem considered thus is a set $(\alpha_1,..., \alpha_n;\ LIL_1,...,LIL_n;\ UIL_1,...,\ UIL_n;\ s_1,...,\ s_n; t_1,...,t_n)$, which can be denoted as an array of n characters X_i, each character possibly associated with two inspection limits LIL_i and UIL_i and two sampling parameters $s_i;t_i$ for the corresponding stage. For example the vector $\left[F^{10.9}_{9.1} \quad N^{21.8}_{18.2} \quad S^{32.3\|100}_{27.7\|1} \quad F^{42.7}_{37.3}\right]$
denotes a 4-stage MSPS with full inspection in the first and last stage, no inspection in the second stage, and sampling

inspection in the third stage - with the associated sampling plan (100,1). From the corresponding numbers, we read that inspection is performed between the limits 9.1 and 10.9 for the first stage, and so on for the other stages.

The basic idea is to start of with a population of *M* possible solutions to the problem (we used a population size *M* of 50). From this pool of initial solutions, some are selected (parents) to construct new solutions (children). The construction algorithm for the initial population consists in randomizing the characters (*N, S, F*), and randomizing the limits by allowing (symmetrical) variation from the original limits by a certain user defined percentage (5% is applied in our examples). We assume symmetrical inspection limits.

Objective Function Evaluation

For every candidate solution its fitness as a possible parent has to be evaluated, where fitness refers to measure of profit or goodness to be maximized while exploring the solution space. We use a straightforward normalization procedure.

The fitness value *f* for each solution *j* in a population of *M* solutions is calculated as:

$$f_j = \frac{1/TIC_j}{\sum_{k=1}^{M}(1/TIC_k)}$$

Parent Selection

Parent selection for producing offspring is done as in Holland's original Genetic Algorithm: for each reproduction two parents are chosen - one parent is selected on its fitness basis, the other is chosen randomly. The idea behind this is that the parent chosen for its fitness ensures genetic quality, while the random parent ensures genetic diversity.

Reproduction

The reproduction process makes use of the genes of the selected parents to produce offspring, or the next generation. Crossover operators exchange segments of the parents to build children. After filling the entire new population with offspring (new solutions), this generation of solutions can replace the previous one entirely or partially, a population size of *M* being maintained throughout the course of the EA. Generating offspring is performed in two steps: first crossover is applied, then the inspection limits are adapted. After these two steps, reproduction is completed and the children thus obtained can populate the new generation. This way, the simultaneous determination of inspection parameters is achieved. We allow the children's inspection limits to deviate from the parents' limits by a certain user defined percentage (5% is applied). Our crossover operator randomly selects a crossover point, and constructs two new solutions by exchanging the tails of both parents.

CONSTRUCTION OF A TEST SET, COMPUTATION AND DISCUSSION

Since -to the best of the author's knowledge- no standard test sets exist in literature, one is built to explore the characteristics and possibilities of the proposed EA metaheuristic. The different test cases are presented below and consecutively the results are discussed.

In the test set are 10 four-stage processes, in every case the value of the quality characteristic changes from 0 to 40 in 4 steps of 10; it was compiled in such a fashion that the expected value after each process step is the same. Step 1's result always is a draw from a normal distribution, the mean equal to 10, and varying standard deviations. For cases A through J, steps 2 through 4 each consist of the addition of another draw from a normal distribution with mean equal to 10, and varying standard deviation. Moreover, the penalty cost is varied (see Table 1), while the test and rework costs for each stage are kept constant for all cases (see Table 2). All these assumptions allow for the same inspection strategy to be used as initial solution for all cases, in order to rule out the influence of the initial solution.

Table 1: Settings for Cases A → J

Case	A	B	C	D	E
All Steps	σ =.1	σ =.1	σ =.1	σ =.2	σ =.2
Pen Cost	1 000	10 000	100 000	1 000	10 000
Case	F	G	H	I	J
Steps 1&3	σ =.2	σ =.2	σ =.2	σ =.1	σ =.01
Steps 2&4	σ =.1	σ =.1	σ =.01	σ =.2	σ =.2
Pen Cost	1 000	10 000	1 000	1 000	1 000

Table 2: Fixed Parameters for All Cases

	Test Cost	Rework Cost
Step 1	1	100
Step 2	1	200
Step 3	1	300
Step 4	1	400
Lower specification		39.6
Upper specification		40.4

Table 3: Results

case	winner solution vector				TIC
A	N	N	N	N	45900
B	$S_{9.940\Vert 0}^{10.060\Vert 25}$	N	N	$F_{39.595}^{40.405}$	67255
C	$F_{9.988}^{10.012}$	N	N	$F_{39.595}^{40.405}$	102590
D	$S_{9.790\Vert 1}^{10.210\Vert 100}$	N	N	$S_{39.592\Vert 1}^{40.402\Vert 50}$	133450
E	$F_{9.929}^{10.071}$	N	$F_{28.566}^{31.434}$	$F_{39.5957}^{40.403}$	178940
F	$F_{9.834}^{10.166}$	N	N	$S_{39.583\Vert 0}^{40.417\Vert 25}$	102935
G	$S_{9.966\Vert 0}^{10.034\Vert 25}$	N	N	$F_{39.594}^{40.406}$	138015
H	$S_{9.835\Vert 1}^{10.165\Vert 100}$	N	$F_{29.575}^{30.425}$	N	72550
I	N	N	N	$F_{39.582}^{40.418}$	73520
J	N	N	N	$F_{39.589}^{40.411}$	58840

Discussion

A glance at Table 3 leads to the following observations:

- If a form of inspection is selected after the final process stage, the selected inspection limits almost

- coincide with the specification limits (39.6, 40.4). This illustrates the capability of the EA algorithm (which has the ability to select its own inspection limits for each stage) to find cost optimal inspection strategies - at least for the final stage.
- Apparently for this group of processes, it is never worthwhile to perform inspection after the second process stage, regardless of process and cost parameters. Inspection after the third process stage is only justified in specific cases (very high relative penalty cost, case E; relatively large process variation added specifically in stage 3, case H)
- Diverse inspection strategies are opted for after stage 1; in a lot of cases it does apparently pay off to counter variation, one way or another, already at such an early stage in the process.

The cost optimal inspection strategy for case A seems to be not to perform inspection whatsoever.
Cases B and C differ only from case A in penalty cost (see Table 1). An immediate effect of these higher penalty costs on the optimal inspection strategy is that full inspection after the final process stage becomes worthwhile for cases B and C. And apparently, inspection after the first process stage also pays off. For case B the cheapest (25,0) sampling plan is chosen, while for case C, where the penalty cost is raised even higher, full inspection after the first stage is opted for.
Case D introduces larger process variation (the standard deviation is doubled from 0.1 to 0.2 in all process stages). The outcome on the inspection strategy is the introduction of sampling inspection after the first and last process stage, compared to the NNNN strategy of case A. For case E, which has the same process variation as case D but a higher penalty cost, performing even more inspection is paying off: full inspection after three of the four process stages is cost optimal.
Comparing cases A and D, and cases B and E in pairs (both pairs have equal penalty costs but different process variation) nicely shows the combined influence of the cost and process parameters on the inspection strategy.

Cases F, G and I have larger process variation than case A, but, unlike cases D and E, not in all process stages. Case H and J have larger process variation in 2 stages, and reduced process variation in the other 2 process stages (see Table 1).
Cases F and G are the same but for the penalty cost. The effect of the raise in penalty cost is a justification of full inspection after the final process stage for case G compared to sampling inspection for case F.
Final full inspection is selected in cases G, I and J. For case G the justification is the higher penalty cost, while for cases I and J large variation is added in the final stage, so it makes sense to have full inspection there. In case H, large inspection is added in process stage 3, while the final process stage brings quasi no extra variation. This is reflected in the optimal strategy for case H where full inspection after stage 3 is selected and the final stage is left uninspected. In cases B through H, in each case some form of inspection after stage 1 is selected; in cases I and J not.
For case I and J, a form of inspection after stage 2, where large process variation is introduced, could be expected, but this is not confirmed in the results. Cost-wise it apparently suffices to sort it all out after the final process stage.
Specifically comparing case A to case J shows that the extra variation introduced in stages 2 and 4 of case I, compared to case A, justifies final inspection, but not inspection after stage 2. Including case J in this comparison shows that the reduction in variation for stages 1 and 3 of case J, compared to case I, cannot compensate for the large variation that is added anyhow in stage 4 and thus cannot render the final inspection superfluous.

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

An optimal inspection strategy for a so-called serial multistage production system (MSPS) has to decide on the location of inspection stations and their inspection limits and sampling parameters, to minimize total expected inspection costs. To our best of knowledge, this paper contains the first attempt at jointly optimizing all MSPS inspection parameters. Simulation is used to model the multistage production system subject to inspection and to calculate the resulting inspection costs, an Evolutionary Algorithm is suggested to optimize the inspection strategies. A test set is proposed, its computational results illustrate the potential of this EA metaheuristic for optimizing quality inspection.
Since no standard test sets are available, further research is needed on designing problem instances for evaluating or benchmarking solution approaches for inspection strategies for multistage processes. EA model extensions could accommodate features such as imperfect inspection, asymmetrical inspection limits or a dynamic determination of the number of simulation runs.

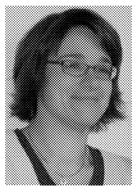
REFERENCES

Holland, J. H. 1975. “Adaptation in Natural and Artificial Systems”, University of Michigan Press.

Van Volsem, S. 2006. “A method for determining cost-efficient inspection strategies for multi-stage production systems”, PhD Thesis, Ghent University, 167 p., ISBN 90-8578-055-1.

Van Volsem, S., W. Dullaert and H. Van Landeghem. 2007. “An Evolutionary Algorithm and Discrete Event Simulation for Optimizing Inspection Strategies for Multi-Stage Processes”, *European Journal of Operational Research,* 179:3, 621-633.

AUTHOR BIOGRAPHY



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COLLABORATIVE PROJECTS

MODELING GLOBAL PRODUCT DEVELOPMENT PROJECTS – THE IDEA OF THE PRODUCT COLLABORATION INFORMATION MODEL

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ABSTRACT

An empirical investigation in product development shows that re-engineering processes have influenced organizational structures and operational processes due to the rising number of international development cooperation. Companies are faced with new challenges which have arisen in so called global product development projects: They have no experience in organizing global teams, no instructions in ingeniously using information and communication technologies (ICTs) in virtual meetings and no idea which technology should be used to support global product development.
One key factor to cope partly with these challenges is to introduce standardized collaboration processes to get the information during the processes when it is needed. Another key factor is to analyze the organizational structures to manage global teams in a right way. However the core of product development is the three dimensional geometric model, which includes further information in form of metadata (following the idea of the integrated product model). This contribution aims to connect new organizational structures and collaboration communication processes in virtual work environments with a product collaboration information model. This three dimensional geometric model should integrate vital information for such global product development projects.
This contribution will take into account the changes in organizational structures and operational processes and find out the role of the product collaboration information model in global product development projects. Furthermore this document describes an approach for modeling these three components which on the one hand should be part of the development process and on the other hand should give an advice for managing global product development projects.

INTRODUCTION

In the globalized economy, organizational structures and methods used in product development have changed. Companies and organizations have responded by re-engineering involved processes, increasing the use of information and communication technologies. But why has product development gone global? Beside the three factors of the magic triangle to make more benefit, to reduce development time and to produce higher qualities, a lot of advantages for the global product development processes can be achieved. Customer's requirements can be integrated earlier in the product development process. An engineer located on the sales market can understand costumers' needs and feelings in a better way than located far away. Today it is essential for companies to be represented on global market to be competitive. Furthermore in global product development worldwide dispersed engineering expertise can be combined on one project. In global dispersed projects experts are able to work on several projects on the same time without leaving his location.
The partitioning and/or distribution of development and production in global working environment have been taken place since years. In contrast to the distribution of development partitioning is relatively new. Worldwide networked locations are the assumption for applying new information and communication technologies (ICTs). Web-based engineering software makes it possible to modularize the product development process in design, simulation, calculation etc. Companies as well as engineers are faced with the new working situation.

GLOBAL PRODUCT DEVELOPMENT PROJECTS

An empirical investigation is dedicated to show the different streams in global industrial product development projects. The results are needed to identify and specify the scenarios for modeling global product development projects and to figure out the information, which is vital for carrying out dispersed development processes. Interviews with experts in global industrial projects show tendencies in global product development and reasons for going global.

Streams in global product development projects
One of the reasons for re-engineering the product development processes is based on new organizational strategies. The fusion of companies forces organizations to restructure mostly redundant development departments to reduce development costs. Development departments across the globe compete one with another to survive. The lack of trust in this kind of global development projects leads to less transparency in knowledge, information and data sharing.
Original equipment manufacturers (OEMs) often mutually cooperate to become more competitive. The idea to share development expertise should lead to new innovations and should also reduce development expenses. In this case the cooperation partners are often at the same knowledge and authorization level.

To reduce costs and to compensate for the less number of German engineers, more and more product development projects are outsourced. The outsourced projects are mostly closed development projects of components or technical systems. The development results are adapted in intersections in firm defined assembly spaces. In this case the hierarchical structure is clearly defined: the employer makes the conditions for the development process including milestones and clarifies the expected development results. The customer is bounded to the employer's requirements. Managing teams across the globe is challenging, particularly working across different time zones.

One tendency is the vision to work 24 hours 7 days a week on one design project across different time zones. Realizing the so called "follow the sun"- project should reduce development costs [Gier-01]. In this case design and product development knowledge have to be formalized.

RE-ORGANIZATION OF PRODUCT DEVELOPMENT

The different streams in global product development need different organizational structures and operational processes, appropriate strategies in managing global teams and suitable technologies for communication. In addition to, the product development works with highly sensitive development data. The different kinds of global product development projects impact the authorization spaces of development data.

Organizational structures

Global product development is always organized in projects, which are arranged in team work. These global development projects are usually embedded in standard organization structures. Therefore the project organization can vary between staff project organization, pure project organization, or matrix project organization. [HeLe-05]

Global product development projects are organized analog to virtual organizations. The definition of virtual organizations as cooperation is the fusion of companies to combine worldwide distributed expertise in a definitive time span to make benefit and to be competitive in the global market. Characterizing for virtual organizations is that these kinds of projects are often arranged without investments [BuWW-03] [Hans-06] [Inno-08]. [GPFe-08] and deal with engineering collaboration in virtual organizations. In Figure 1 the virtual organizations are integrated in the classical organization models [PiRW-03] [Reic-98]. Realizing virtual organizations is driven by innovative developments of ICTs.

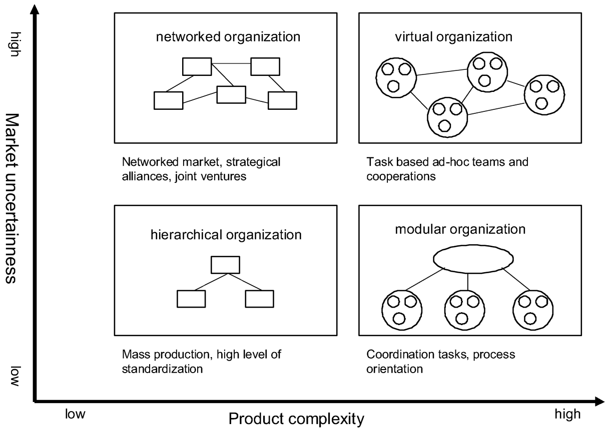

Figure 1: Organization Maturity

Fact is that cooperation becomes more complex in dispersed interdisciplinary team work. The effort to meet the requirements on cooperation arises [StLe-01]. Cooperation means the efficiently work-sharing to achieve better working results between dispersed employers, organization divisions or organizations [Schm97]. Cooperation in context of computer supported cooperative work technology is called tele-cooperation [Remö00].

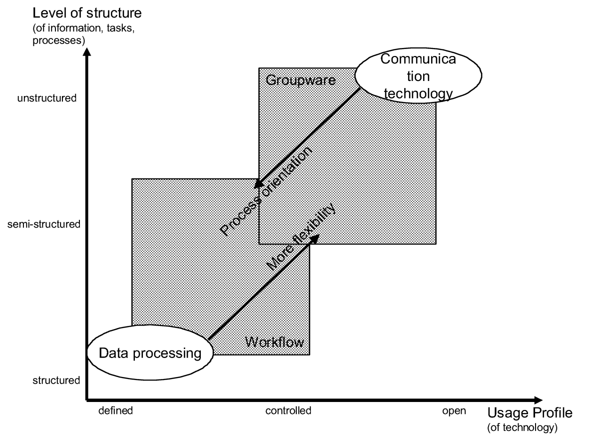

Figure 2: The Application of Technology in Global Product Development

CSCW-Technologies

"Computer Supported Cooperative Work (CSCW) is a generic term which combines the way people work in groups with the enabling technologies of computer networking and associated hardware, software, services, and techniques" as outlined by Wilson in [Ande-07]. CSCW-technologies resolve the limitation of time and space in collaboration, thus team meetings can take place anywhere and anytime.

A classification of CSCW-technologies regarding time and space in the CSCW-Matrix was developed by Johansen in 1988 [Joha-88]. Burger [Burg-97] integrated the classification of CSCW-technologies in the 3C-Model (communication, coordination and cooperation) of Teufel.

Tools providing the possibility to communicate can be subdivided into tools enabling asynchronous and synchronous communication. Communication tools can be used individually or can be connected with further Groupware systems. Coordination tools should enable an

unhindered and efficient flow of work in collaboration. Coordination can be processed by the project members themselves by using the aforementioned communication tools or by special workflow management systems. Workflows should advance the project's progress in coordinating activities and resources of team members. Systems for coordination also enable access to development data and allow for easier administration of the project information. Cooperation tools should fulfill different requirements depending on the project phase. Therefore a number of systems are needed with various applications, such as permitting synchronous as well as asynchronous working on common documents.
E-Collaboration Systems, Groupware Systems and web based Conference Systems integrate different aforementioned CSCW-applications for communication, cooperation and coordination to support various scenarios. Web based Conference Systems have been established for applying synchronous virtual meetings, whereas E-Collaboration Systems are information systems, which professionally support data and information exchange by included workflow management and life cycle functions.

Product development technologies

In product development special software tools are developed to support the requirements of this highly information sensitive working sector. To manage information product data management systems (PDM-Systems) are developed. The product data management functions are implemented in order to take on different data management tasks, like for example user management, product structure management, configuration management, version management, release and change management as well as project management. In summary PDM-Systems store and administrate different kinds of data as well as permit the access to data. To enable collaboration between widely distributed engineering centers special internet based collaboration platforms are integrated.
In current collaboration platforms more and more CSCW-applications are integrated. Collaboration platforms are entitled to act as a connection point for distributed developers where interactions for developing products should take place. Recently integrated social software functionalities should trigger developers to share their information and knowledge. These new functionalities enable a new kind of thinking and working structures in product development. A software investigation shows that development projects aren't sufficiently supported by cooperation functions in engineering tools [AVRo-08]. The implementation of social software functionalities is one step towards making it possible for dispersed developers to cooperate.
Assumption for choosing suitable ICT and engineering tools in distributed projects is to analyze cooperation connections in cooperation. Cooperation is based on communication. The right choice of ICTs is named as the critical success factor in [SSUn-01].

Global Teams

In the globalized economy more and more companies decide to develop products in global fields. Global teams are both geographically dispersed and culturally diverse. They work together in virtual working environment. Communication only takes place supported by technology. The team members working together networked seldom know each other personally. Furthermore, the multinational global teams are mostly embedded in different organizational structures.
The team mates live in different time zones. On the one hand product development in multicultural field can evoke synergy effects. "Such teams have the potential to provide companies with a more practiced and economical way to develop new products and services."[DKBa-01] It is said that products developed in intercultural teams are more innovative and perform better than conventionally developed products. But on the other hand research suggests, however, that these companies are struggling to deal with the myriad problems arising from the use of such global teams [BAHs-97]; [BGMR-98]; [DoKa-96]; [DKGr-99]. Much of this struggle seems to stem from the nature of global teams.
The challenges can be subdivided in challenges for personal interaction in global teams and for managing them. The team members have to cope with different languages and have a different set of cultural belief in their team. These often lead to misunderstandings and more room for interpretation in discussions and decision making. Different countries have a different focus on skills, mirrored by education and working attitude of the team mates. One key difference is the different approach to work in various companies. Cooperation companies have to combine different methods and processes which are often stem from different historical backgrounds.
Managing global teams is the most difficult issue as many investigations are dedicated. In these investigations success or failure are attributed by the management of global projects. In global distributed working environment it is difficult for an engineer to get the right information as soon as it is needed. The circulation of information and knowledge has an important role in product development process. In addition to cooperation between companies there is often non-uniform technical support. But last but not least these aspects make it complicated for project managers to build a common project goal and task strategy as well as cohesion between the team members.
The following table lists the management tasks investigated by a research group at a Northeastern University in Boston, Massachusetts [BMDo-06]. The investigation was an empirical study in 300 companies over ten years.

Challenge	Steps Required to Meet the Challenge
No. 1—Members who speak different native languages.	• Send critical documents and material to all team members. • Allow time for members to digest and respond to information. • Develop and distribute written records of all meetings. • Educate team members about challenges of communication in such a team. • Work with members to create common terminology with clear definitions.
No. 2—Members with different cultural backgrounds.	• Be aware of and sensitive to cultural diversity. • Possess strong interpersonal/communication skills. • Learn about cultures of individual team members. • Offer cultural diversity training. • Engage team members in discussions about their respective cultures. • Understand that face-to-face interaction is critical in some cultures.
No. 3—Members living/working in multiple countries.	• Hold a face-to-face meeting at beginning of project. • Hold project progress meetings throughout project. • Send information and materials prior to each meeting. • Keep track of team member participation during meetings. • Engage all members during team meetings. • Summarize each meeting and the decisions made and distribute to all team members for feedback. • Vary timing of meetings to accommodate different time zones.
No. 4—Members from different companies.	• Select team members with strong personal networks. • Provide time for team members to get to know one another. • Help team members identify mutual interests and needs. • Have team members work together and interact socially. • Facilitate continual interaction amongst team members.

Tabelle 3: Herausforderungen und Vorgehensweise für Managers

Figure 3: Challenges in Global Teams

CHANGING PROCESSES – OPERATIONAL STRUCTURE OF GLOBAL PRODUCT DEVELOPMENT

Processes generally describe sequences of activities within an enterprise. They are actually carried out within the framework of operational project management [ProS-07]. In cross-enterprise networks lots of processes have been changed. This paragraph will take into account the changes in personal interaction in global product development.
Basically all communication processes have changed in global product development projects. Groupware as well as special communication tools enables the synchronous and asynchronous communication in teams across the globe. The choice of communication tools depend on the richness of the communication that means how important the transferred information for the results of the task is. In distributed team work, communication is more focused on the project tasks because as aforementioned the team mates often do not know each other. The social component of communication is often missing. On the one hand this aspect advances the project process, but on the other hand trust plays an important role in the project's success.
The disadvantages of CSCW-technology use is that team members are confronted by a flow of redundant information. Due to working in different time zones decisions can not make ad hoc. asynchronous CSCW-technology compensate for this time span in distributed projects across the globe. [SHSS-97]
Challenging processes in global product development are the processes of decision making and problem solving in virtual working environment. Decision making is difficult at all but global teams are faced with the problem that they don't know each other and therefore cannot estimate the knowledge and information level of the team mates. [Auer-98] describes the key factors influencing decision making in groups, including the information level as well as sociological and socio-cultural issues. In product development decision making basically takes place based on facts, like costs, security and collisions between parts. Thus global meetings for decision making should be well prepared. First of all the actors need preparation in tele-cooperation systems, for example the way how to deal with videoconference systems. Subjects, respondents and actions should be well defined before starting a global virtual meeting.
In global product development an approach has to be found to make design reviews. Relatively easy communication ways can become very complex in virtual working environments.

PML – AN OBJECT ORIENTED PROCESS MODELING LANGUAGE

PML, the Process Modeling Language, has been introduced in [AnMR-08], [AnRR-08], and [AnRa-08]. This chapter gives a short overview about the basic concepts and introduces a new event model for PML, which enables integral modeling of organizations.
PML has been derived mathematically from UML in an abstract way to get a process object from an information object [AnMR-08]. This enables PML to use most of the UML notations and all of the object oriented modeling concepts [Oest-06]. The main idea behind this technique is that a process is a generic construct, which is modularizeable, exchangeable, extendable and very flexible. Thus a process is highly reusable and does not have to be (re-)modeled for every new product – or say project. This leads to the next concept: a process is a generic description of implementable workflows and can be instantiated. As soon as a process is instantiated it gets a project and the process parameters, which have been defined in a generic way, will now be specified with real world data.

process
methods (event list): event
resources

Figure 4: PML Process Class Diagram

Figure 4 shows the principal PML process class diagram. The first field holds the name of the modeled process, which should be meaningful for clearness of the process model. The second field lists all the methods ("synonyms": activity, operation) that are members of this process. Those methods can be other processes, modeled as aggregations, or atomic activities. The last field lists the resources needed for this process, like machines, algorithms, employees etc.
The above mentioned aggregation of methods leads to one of the main concepts of PML, or object oriented modeling in general. PML supports, as UML does, inheritance, which leads to generalization und specialization, and three types of aggregations: association, aggregation and composition. Those concepts support hierarchical modeling of processes, which is necessary for flexibility, extendibility and reusability. Inheritance means that processes can be grouped by using a common super class, which defines common methods or resources or at least a common kind of process. E.g. the processes drilling, milling, and turning can be grouped using the super class chipping. Associations, aggregations, and compositions have the same meaning as used in UML and support hierarchical structures particularly regarding to modularization and extension of the process model.
In Figure 4 the central field lists the methods. A method can get a list of events as parameters and may return an event as result. This basically is the new event model introduced in PML. The importance of this notation is quite obvious. A method starts running as soon as all events from the parameter list have appeared. E.g. a change process listens for a change request and starts as soon as a change request appears. If more than one condition has to be fulfilled the event list holds more than one event and all have to become true to trigger the start of the event. On the other side, a method may return an event, e.g. to express that its runtime has elapsed, certain information has been gathered etc.

event
information list

Figure 5: PML Event

To get fine grained event models a new element is introduced, which is shown in Figure 5. An event class is similar to a UML or PML class, except that it only contains 2 fields: a name field and a information list field. The name field again defines the name of the event and should have a unique identifier. The information list holds information or data, which results from the runtime of the process and may be needed for the following processes. Information can be calculation results, design data, a decision etc. Using unique identifiers for events and using events as parameters and return values of methods the process sequence is explicit and controllable. Hence activity diagrams or sequence diagrams are redundant and thus not needed, but optional.
Events, as they are classes, can be inherited to use object oriented concepts for event modeling. This may be helpful for example to group events and listen for certain types of events. Imagine a process where every activity has to be logged, so there would be a process that listens to every occurring event to log the success or failure of an activity.

3 VIEWS TO AN ORGANIZATION MODEL

Companies can be described to be built up on three planes: an organizational plane, a data plane, and a process plane.
The organizational plane is well structured and describes the company's resources. It can be built up as a hierarchical structure, a matrix structure, or a modular structure, see Figure 1. However, the organizational plane describes business units, divisions and departments, employees and their membership to departments, projects, or groups, and finally the physical resources of a company.
The data plane defines the product data and the product structure. The product data not only consists of geometric data, production information, simulation results, etc., but also includes meeting records, and thus minutes from the decisions. Product data is typically stored and administrated by product data management (PDM) systems.
The third plane is the process plane. Particularly for complex products the development will not start before the process definition has been completed. Hence the process plane is the dominating plane of a company's organization.
Figure 6 shows the 3 planes in a principal way. It is important to note, that the 3 planes are orthogonal, which basically means they are independent from each other, but are linked together – the dominating plane for the interdependence is the process plane. If a company restructures their organizational or process plane, they may introduce a certain amount of dependencies between the planes, but they also may outsource several processes or include external organizational units to fulfill the process requirements. This clarifies the orthogonality of the three planes.

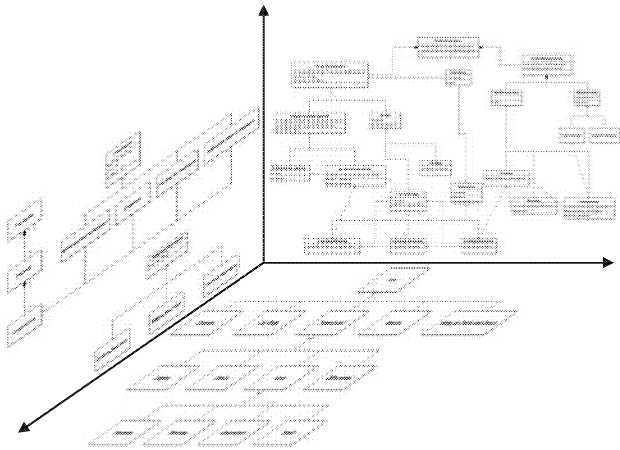

Figure 6: 3-Planes Organizational Structure

Using UML and PML the 3-plane organization model can be implemented in an easy, consistent, uniform, and object oriented way. Although the data model and the organization model do not necessarily have to be modeled with UML, PML is designed to integrate links to UML descriptions of the 2 orthogonal planes.
The PML resources work best if they are UML classes from the organization plane. This leads to high integrity of the process model. In the above chapter event classes have been introduced with information lists. They are designed to be UML classes from the data plane. Thus every process information is storable and accessible in the data plane, which shows the fundamental idea of the new event model.
Also supplier integration is easy and powerful using PML, or more precise the UML / PML 3 plane organization model. Supplier integration then is just specialization of the process data, and organization model.

PRODUCT COLLABORATION INFORMATION MODEL

In this chapter the idea of the product collaboration information model is described. The product collaboration information model (PCI-Model) is based on a three dimensional geometric model with further information for collaboration. The model is built on three information levels: organization and process information integrated in a current geometric state recording of the developed product.
The geometric state records are modeled in the data plane and hold links to the organizational plane. Thus the corresponding responsibilities can be addressed in the data plane. The update of the data is driven by the process model and generates events, which may start new processes, e.g. change requests. The PCI Model fits into the 3-plane organization model and is designed to support global cooperation processes.
In this paper the idea of the PCI-Model is shown by the example of a decision making process. Research has to be done for extending the PCI model on further processes, for example design reviews and change management.
The PCI-Model should represent the status of the product model including all states of changes and releases. Changes and releases are a result of a decision making process. Annotations in form of dialog maps represent the process which has lead to a decision. Who argued why? Furthermore

the decision making process includes different organizational structure information, for instance who was responsible for the change, which team worked at the model and when as well which organization locations where included.
Including an evaluation about the used technology for realizing the decision making process, the PCI-Model gives an advice for further virtual meetings.
In global product development it is important to include information about the process as well as the organization. The PCI-Model should be used for long-term archiving where all results should be included as lessons learned. This can be basis for further knowledge management in global working environments.

CONCLUSION

In this paper a new event model for PML, the Process Modeling Language, has been introduced and it has been shown, how this event model fits into the object oriented design of PML. To model all relevant data, structure and processes a 3-plane organization model has been introduced and the orthogonality of the three planes has been shown. Furthermore the dominant role of the process plane has been shown and the interdependency to the data plane and the organizational plane. With the introduction of the Product Collaboration Information model (PCI) the interdependency between data and resources has been shown and why they are needed to support a global distributed collaboration project.
In future works the details of the PCI model have to be addressed to get a fine grained description of needed data for certain levels of collaboration. The PCI model will be modeled with UML and be linked to a generic PML model to show why PCI is needed to support global distributed cooperation and which levels can be addressed.

REFERENCES

[AVRo-08] Anderl, R.; Völz, D.; Rollmann, T.: Knowledge Integration in Global Engineering in Enterprise and Interoperability, Springer Verlag, 2008

[AnMR-08] Anderl, R.; Malzacher, J.; Raßler, J.: Proposal for an Object Oriented Process Modeling Language in Enterprise Interoperability III, Springer-Verlag London Limited, I-ESA 2008, London, Berlin, 2008

[AnRR-08] Anderl, R.; Raßler, J.; Rollmann, T.; Wu, Z.: PML in Application – An Example of Integral Sheet Metal Design with Higher Order BIfUrcations, ASME 2008, New York, USA, 2008

[AnRa-08] Anderl, R.; Raßler, J.: PML, an Object Oriented Process Modeling Language, IFIP 20th World Computer Congress, Proceedings of the Second Topical Session on Computer-Aided Innovation, WG 5.4/TC 5, Springer Boston, 2008

[BAHs-97] Benson-Armer R, Hsieh TY.: Teamwork Across Time and Space; The Mc Kinsey Quaterly; 4:18-27; 1997

[BGMR-98] Boutellier R, Gassmann O, Macho H, Roux M.: Management of Dispersed Product Development Teams: The Role of Information Technologies; R&D Management; 28:13-25; 1998

[BMDo-06] Barczak, G., McDonough, E.F.: Athanassiou, Nicholas:"so you want to be a global project leader?", Research-Technology Management, Industrial Research Institute, 2006

[BuWW-03] Bullinger, Hans-Jörg; Hans Jürgen Warnecke, Engelbert Westkämper (Hrsg.): Neue Organisationsformen im Unternehmen – Ein Handbuch für das moderne Management. 2., neu bearbeitete und erweiterte Auflage, Springer Verlag Berlin, 2003

[DKBa-01] Mc Donough, Edward F.; Kahn, Kenneth B.; Barczak, G.: An investigation of the use of global, virtual, and ollocated new product development teams; The Journal of Product Innovation Managemenu; page 110-120, 2001

[DKGr-99] Mc Donough EF, Kahn KB, Griflin AJ.: Managing Global Product Development Teams: Achieving Effective Performance by Linking Communications Speed, Complexity and Scope; IEEE Transactions on Engineering Management, 46 (4); 1999

[DoKa-96] Mc Donough EF, Kahn KB: Hard and Soft Technologies for Global New Product Development; R&D Management; 26:241-253; 1996

[Gier-01] Gierhardt, H.: Global verteilte Produktentwicklungsprojekte, Dissertation an der Fakultät für Maschinenwesen an der Universtiät München, ISBN 3934767680, 2001

[GPFe-08] Gautier, G., Piddington, C., Fernando, T.: Understanding the Collaborative Workspace in Enterprise Interoperability, Springer Verlag, 2008

[Hans-06] Hansmann, Karl-Werner: Industrielles Management. 8., überarbeitete und erweiterte Auflage, Oldenbourg Verlag 2006

[HeLe-05] Heinrich, Lutz J.; Lehner, Franz: Informationsmanagement. Planung, Überwachung und Steuerung der Informationsinfrastruktur. 8. Auflage Oldenbourg Verlag 2005

[Inno-08] Homepage „Das innovative Unternehmen – Das virtuelle Unternehmen als innovative Organisationsform. Abgerufen unter http://www.innovation-aktuell.de/kl0817.htm am 25.07.2008

[Oest-06] Oestereich, B.: Objektorientierte Softwareentwicklung. Analyse und Design mit UML 2.1, Oldenbourg Verlag, München, 2006

[PiRW-03] Picot, A.; R. Reichwald, R. Wigand: Die grenzenlose Unternehmung- Information, Organisation und Management. 5. Auflage, Gabler Verlag Wiesbaden 2003

[Reic-98] Reichwald, R.; K. Möslein, H. Sachenbacher, H. Englberger, S. Oldenburg: Telekooperation. Verteilte Arbeits- und Organisationsformen. Springer Verlag, Heidelberg 1998

[Remö-00] Reichwald, R. Möslein, K., Sachebahcer, H., Englberger, H.: Telekooperation. Verteilte Arbeits- und Organisationsformen. 2. Auflage Berlin Heidelberg New York 2000

[Schm-97] Schmidt, D.O.: Unternehmenskooperationen in Deutschland. Voraussetzungen und Verbreitung. Wiesbaden 1997

[SSUn-01] Schwabe, G.; Streitz, N., Unlaund, R.: CSCW-Kompendium – Lehr- und Handbuch zum computerunterstützten kooperativen Arbeiten, Springer Verlag Berlin, Heidelberg, New York, 2001

[StLe-01] Steinheider B., Legrady G.: Kooperation in interdisziplinären Teams in Forschung, Produktentwicklung und Kunst. In: Mensch & Computer, Stuttgart Teubner, S. S. 37-46., 2001

ONTOLOGY MATCHING FOR COLLABORATIVE ENGINEERING

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KEYWORDS
Collaborative engineering, knowledge sharing, common language, ontology, ontology matching, semantic matching.

ABSTRACT

Collaborative Engineering is a knowledge and communication intensive process which requires a common communication language agents can read and understand. Ontology, defined as a shared description of concepts and relationships of a domain expressed in a computer readable language, has appeared as a promising solution to this problem. But, using the same ontology is not a realistic solution since communities of practice use their own ontologies. These ontologies are generally not interoperable. Ontology matching has become the new challenge in collaborative engineering. Nevertheless, if many solutions of matching ontologies exist, there is still no solution that is a clear success. Matching ontologies remains difficult. The main reason lies in ambiguity in semantic interpretation of concepts. After a state of art of ontology matching, this article presents a semantic matching method based on "specific differences" between concepts.

INTRODUCTION

Applications are more and more distributed and engineering has evolved from concurrent to collaborative. Product development, from design to manufacturing, relies on co-operation and collaboration of heterogeneous actors. In order to reach their common objective these actors have to communicate and exchange information: client requirements, business information, simulation results, workshop loads, supplier delays…. (figure 1). Collaborative Engineering is a knowledge and communication intensive process (Olsen et al. 1994), (Gruber et al. 1992).

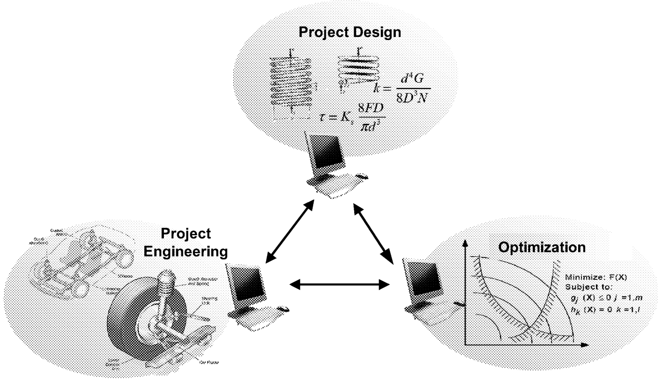
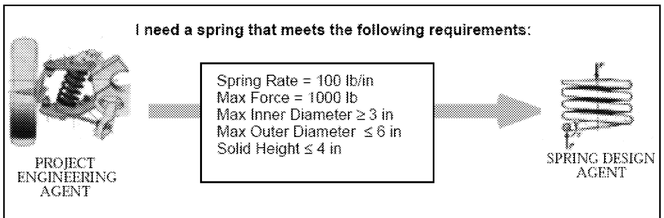


Figure 1: Collaborative engineering

Communication between people, organisations and software systems is difficult due to the fact that each of these actors speaks a different language. To address this problem, we need a common communication language agents can read and understand. Using a single and normalised language like KQML (Labrou and Finin 1997) can reduce the gap of misunderstanding (figure 2). Although there is no syntactic problem left and although such languages give some useful indications about the pragmatic content of the message (by using predefined performatives, i.e. commitment actions, like "tell" and "reply" in figure 2), the semantic problem has still to be addressed.




```
(tell :sender project-engineering-agent
      :receiver spring-design-agent
      :ontology helical-compression-springs
      :content (and (helical-compression-spring SPRING-24)
                    (= (spring.spring-constant SPRING-24)
                       (* 100 (/ lbs in)))
                    (= (spring.max-load SPRING-24)
                       (* 1000 lbs))
                    (=< (spring.outside-diameter SPRING-24) (* 6 in))
                    (>= (spring.inside-diameter SPRING-24) (* 3 in))
                    (=< (spring.solid-height SPRING-24) (* 4 in))))

(evaluate :sender project-engineering-agent
          :receiver spring-design-agent
          :ontology helical-compression-springs
          :reply-with SPRING_DATA
          :content (listof
                    (spring.outside-diameter SPRING-24)
                    (spring.inside-diameter SPRING-24)
                    (spring.length SPRING-24)
                    (component.cost SPRING-24)))
```

Figure 2: Communication between agents (Olsen et al. 1994)

It means that two entities can communicate, and then exchange and share knowledge, only if they agree upon on the meaning of the terms they use.

Ontology, understood as an agreed vocabulary of common terms and meanings shared by a group of people, is a solution to that problem: "an [explicit] ontology may take a variety of forms, but necessarily it will include a vocabulary of terms and some specification of their meaning (i.e. definitions)." (Ushold and al. 96). But ontology can not be reduced to a vocabulary. First of all, ontology is an explicit and formal representation of a domain knowledge. It is what Gruber called "*a specification of a conceptualisation*": "In the context of knowledge sharing, I use the term ontology to mean a *specification of a conceptualization*. That is, an ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents. This definition is consistent with the usage of ontology as set-of-concept-definitions, but more general. And it is certainly a different sense of the word than its use in philosophy." (Gruber 1993).

To resume the most definitions used in knowledge engineering, including semantic web, we can say that: "*an ontology is a shared description of concepts and relationships of a domain expressed in a computer readable language*" (Roche 2003). The reason ontology is so popular is, in large part, due to what they promise: a shared and common understanding of some domain that can be communicated across people and computers. The figure 3 is an example from the generic Upper Cyc Ontology.

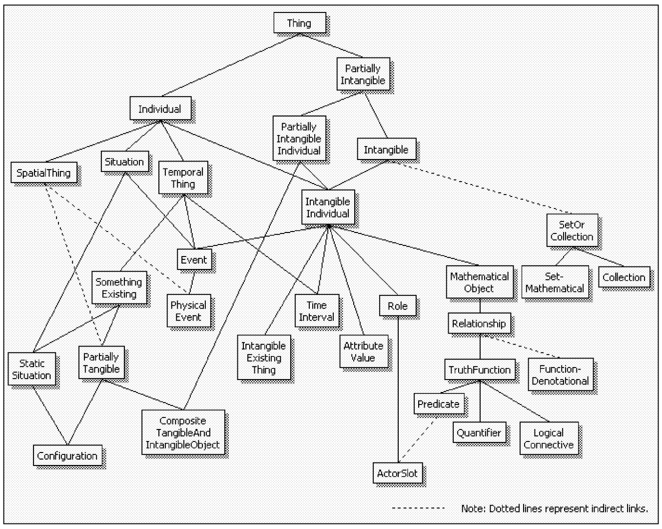


Figure 3: The Upper Cyc Ontology

But collaborators in enterprise work at their own level, using their own knowledge, engineering models and then their own ontologies. These ontologies generally can not interoperate. Managing different ontologies – using a common and shared ontology is not a realistic solution since ontology depends on community of practice – brings up interoperability and communication to a more complex level. Furthermore, the software tools extensively used in information societies, requiring specific and dedicated representations, are more concurrent than collaborative.

The new challenge in collaborative engineering is ontology matching. The next part is dedicated to this subject. It presents a state of art of ontology matching and their methods either syntactic or semantic.

But, if many solutions of matching ontologies have been proposed, "there is no integrated solution that is a clear success" (Shvaiko and Euzenat 2008). Matching ontologies as well as reusing them remain difficult. The main reason lies in ambiguity in semantic interpretation of concepts. The last part of the article presents an ontology matching method based on "specific differences" between concepts.

ONTOLOGY MATCHING

Thinking that a common and centralized ontology can be a solution for communication problems of collaborative applications is unrealistic. Agents work at their own level, using their own knowledge and engineering models which can not be standardized and normalized. Ontology alignment has become a new domain of research coming from the need of integrating heterogeneous models and knowledge representations between agents.

There are a lot of work on ontology matching originating from different communities (artificial intelligence, databases, web semantic, etc.) as well as a lot of different states of art on this subject (Kalfoglou and Schorlemmer 2003), (Noy 2004), (Shvaiko and Euzenat 2005), (Choi et al. 2006). A book, entirely devoted to ontology matching, has also been written (Euzenat and Shvaiko 2007).

In a word, the main goal of ontology matching is to determine the relationships between the concepts of two "heterogeneous" ontologies describing the same domain (Shvaiko and Euzenat 2005). Said in a more formal way, an ontology mapping is a morphism defined between two ontologies sharing the same domain of discourse in such a way that all interpretations that satisfy the axioms of the second ontology also satisfy the translated axioms of the first one (Kalfoglou and Schorlemmer 2003).

Ontologies mismatche at different levels (Klein 2001). The first one is the language level mismatches – also called language heterogeneity – which occurs when ontologies are written in different languages, for example in frame languages or logical languages. This level of mismatches strongly impact the ontology mapping since expressiveness directly depends on the language used for writing ontology.

The ontology level mismatches gather terminological and conceptual mismatches. The first ones concern the names of the concepts. Some of them can be synonyms (different names with equivalent denoted concepts, e.g. "car" used in one ontology when "automobile" is used in another one) or homonyms (the same name in two ontologies has different meanings, i.e. different denoted concepts in the two ontologies). Terminological variations, i.e. writing the same name with slight differences (e.g. "electro erosion machining" and "electro-erosion machining"), as well as rhetorical figures like ellipsis ("electro-erosion" for "electro-erosion machining") are also terminological mismatches. Conceptual mismatches occur when the conceptualizations of the domain are different. It means that the two ontologies do not conceptualize the reality in the same way with the same precision. For example "similar" concepts with different extensions (set of instances) – scope mismatches – or "similar" concepts describing same objects with different levels of details – granularity mismatches.

The relationships between concepts of matched ontologies can be defined in terms of "mapping elements". A "mapping element" is 5-uple (id, c, c', R, n) where id is a unique identifier of the 5-uple, c and c' are respectively concepts of the first and second ontology, R the identified relation between c and c' (e.g. equivalence (≡), more general (>), less general (<), overlapping (∩) or disjoint (⊥)). At last, n represents a confidence measure (in general a number belonging to [0 1]) of the relation R (Shvaiko and Euzenat 2005).

Matching two ontologies consists of building a set of mapping elements. Such a process may require extra-knowledge (resources) like a common ontology shared by the two ontologies to be mapped (see figure 4).

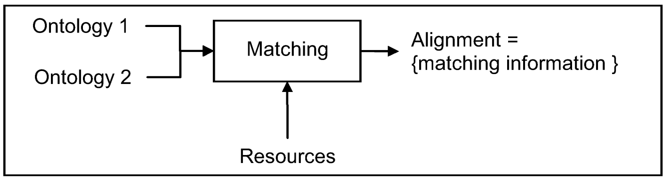


Figure 4: The Alignment process

Relations between concepts are relations of similarity. Different techniques are available to identify theses relationships. They differ according to they are applied to the name spaces of ontologies or to their semantic spaces.

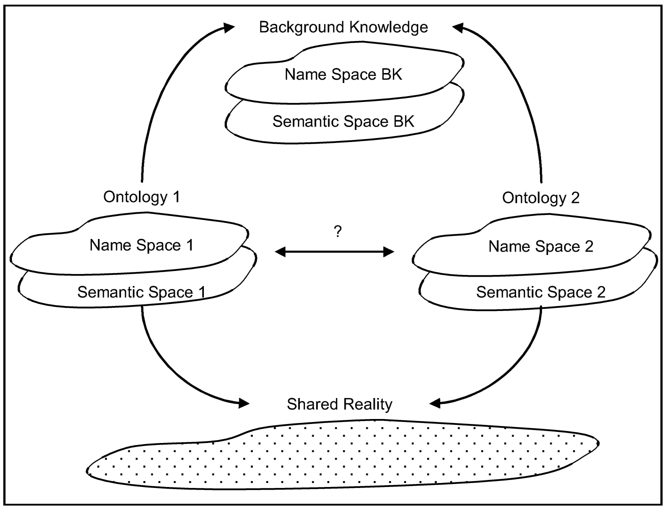


Figure 5: The Name and Semantic spaces

Based on the idea that similarity between names expresses a similarity between their meaning (concepts), the linguistic methods applied to name spaces compare the names of concepts. Such methods include string-based techniques like "prefix" (e.g. int and integer), "suffix" (e.g. phone and telephone), "N-gram" (sequences of n characters) and "edit distance" (i.e. the number of insertions, deletions and substitutions of characters required to modify one string to another). They also include stemming and regular expressions techniques in order to compare canonical forms (mixer rather than mixers). Using linguistic resources, like dictionaries and thesauri, can improve the mapping of names using linguistic relationships like synonymy or hyponymy (camera and digital camera). WordNet (WordNet 1998) is an example of such a resource.

The semantic methods compare the semantic spaces of ontologies. It means to compare the definitions of concepts from an extensional or intensional point of view. From the extensional point of view, two concepts can be compared through their extensions considered as so many sets (the sets of their instances). Relations in mapping elements are then deduced from the set operators applied to extensions.

From the intensional point of view, concepts can be compared according to their internal structure, their external structure (i.e. the relationships between concepts) and according to their logical interpretation (in logic, a concept is a well formed formula).

The internal-structure comparison consists in matching attribute names of two concepts as well as in mapping the data types of attributes (the linguistic methods for matching names can be used). Whereas the external-structure comparison relies on graph matching since ontologies can be viewed as networks of concepts linked by relationships like "is-a" or "part-of" relations. Graph-based methods can be used. Some methods, based on the fact that similar concepts have similar neighbours, define similarity between two concepts in function of similarity of children and/or leaves. Similarity based on logical interpretation relies on formal language like description logics (Baader et al. 2003).

If these string-based and structure-based techniques can produce good results, there are numerous examples in which they fail (Sabou et al. 2006). Using background knowledge allows to improve ontology matching (Sabou et al. 2006), (Giunchiglia et al. 2007). Ontologies represent different local conceptualizations of a same domain. The matching process requires a global knowledge which covers the two ontologies and which will be able to fill the semantic gap between them. Using a reference domain ontology is an example of such a background knowledge. The two ontologies to be matched are first mapped to the reference ontology. Their matching will be then deduced trough the relationships of the reference ontology.

SEMANTIC MATCHING

Today, ontology mapping relies mainly on combining terminological methods (using string-based techniques applied to the names of concepts) and structural methods (considering ontologies as networks of concepts). These methods are more descriptive than semantic when is necessary to fill the semantic gap between ontologies to be matched. "There is no integrated solution that is a clear success" (Shvaiko and Euzenat 2008). Matching ontologies as well as reusing them remain difficult tasks. The main reason lies in ambiguity in semantic interpretation of concepts (Latif et al. 2007).

We claim that is necessary to take into account the semantics of concepts as well as the semantics of the language used for writing ontology. Two ontologies can be mapped only if they conceptualize the same domain of discourse and if they share some common knowledge. Using a reference ontology is a useful means to fill the semantic gap, when such an ontology exist. Using WordNet, one of the most often background knowledge used, is not a satisfactory solution because WordNet is more a lexical network than an ontology (WordNet 1998). It means that WordNet is not a network of concepts, but a network of words (a "synset" can not be considered as a concept. In other words, a set of synonymous does not define a concept).

In order to illustrate our thesis about the importance for ontology matching to take into account the semantics of concepts as well as the semantics of language, let us consider an ontology-oriented language based on the "specific difference" principle (Roche 2001).

In such languages, a concept is defined by "genus-differentia" definition (figure 6). It means that a concept (the species) is defined from a given and previously defined concept (the genus) adding a differentia (the specific difference of the species). Differentiae (differences) are the elementary units from which the meaning of a concept is built: a concept is defined by a set of differences. It implies that an ontology is characterized by a given set of differences which defines an orthonormal basis for the definition of concepts.

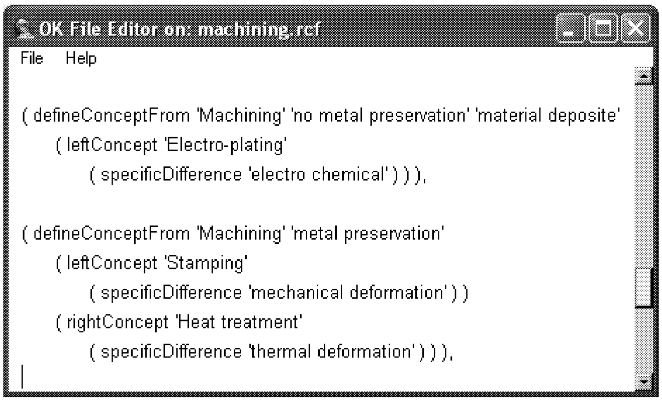


Figure 6: Ontology defined by specific differentiation

Unlike attribute, difference cannot be valued. It neither can be removed from the definition of a concept without changing its nature (for example, in figure 7, 'piece rotation' is a difference of the 'Turning' concept whereas 'rotation speed' is an attribute (attributes are not displayed by the graph editor)). Differences allow to understand concepts when attributes and their values allow to describe the instances of the concepts.

The specific difference principle structures concepts into a Porphyry tree (figure 7). Attributes are attached *a posteriori* to the concepts. Such an approach distinguishes "definition" (i.e. the set of differentiae defining a concept) from "description" (i.e. the set of attributes describing objects subsumed by the concept previously defined by specific differentiation). Let us notice that such Aristotelian ontology can be translated into OWL (Spies and Roche 2008).

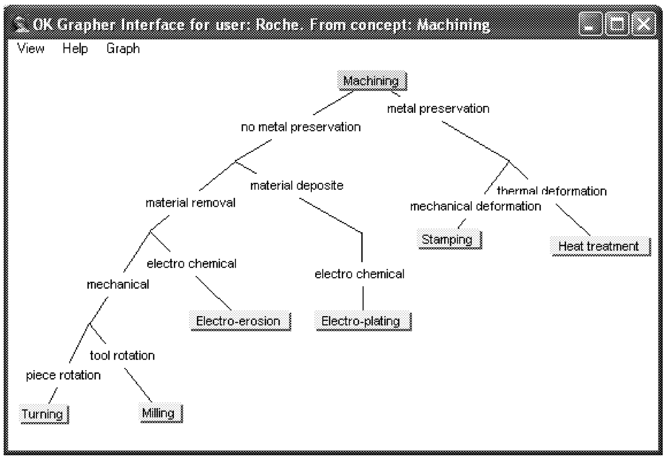


Figure 7: Porphyry tree

We claim that two ontologies can match if they share a common understanding of a same domain. As differentiae express this common understanding, ontology matching is based on "differentia matching".

"Differentia matching" relies on a mapping relation between differences. This relation is defined on the orthonormal bases of the two ontologies. For example, d_1 R_{12} $d_{21}…d_{2n}$ means that the difference d_1 of the first orthonormal basis matches with the differences $d_{21}…d_{2n}$ of the second orthonormal basis (the differentia mapping relation is not necessarily a bijection and the set of matched differences must be compatible between them from the second ontology point of view).

The mapping elements between concepts are deduced from the comparison of the set of the matched differences of the first concept with the set of differences of the second one. For example (id, c1, c2, >) means the set of the matched differences of c1 is included into the set of differences of c2 (the confidence measure in "differentia mapping" is 1).

This approach has been validated in an European project on a multilingual content management system on solar energy (ASTECH project). Terminological techniques could not be applied because of multilingualism. The conceptualization were different whereas some differences were common and it was then possible to match differences between the different orthonormal bases.

CONCLUSION

Communication and knowledge sharing in collaborative engineering require to match ontologies between the communities of practice. Although several methods exist, ontology mapping remains a difficult task. Most of them rely on terminological and/or structural methods when it is necessary to fill the semantic gap between ontologies. We claim that the semantics of the language used for writing concepts, as well as the semantics of the concepts (definition and description should be distinguished) must be taken into account into the ontology alignment process. Such an approach has been validated with a ontology-oriented language based on the "genus-differentia" definition applied to a multilingual content management system.

REFERENCES

Baader F., Calvanese D., McGuinness D., Nardi D., Patel-Schneider P., "The Description Logic Handbook", Cambridge University Press, 2003.

Choi N., Song I., Han H. "A Survey on Ontology Mapping", SIGMOD Record, Vol 35 n° 3, September 2006.

Euzenat J., Shvaiko P. "Ontology Matching". Springer-Verlag 2007

Giunchiglia F., Shvaiko P. "Semantic Matching". In The Knowledge Engineering Review Journal, vol. 18(3), pp. 265-280, 2003.

Giunchiglia F., Shvaiko P., Yatskevich M., "Background knowledge in ontology matching", extended abstract from the Bertinoro Workshop n Information Integration (INFINT), 2007.

Gruber T.R., Tenenbaum J.M., Weber J.C.. "Toward a Knowledge Medium for Collaborative Product Development", Artificial Intelligence in Design Conference, Pittsburgh, USA 1992

Gruber T.R. "A Translation Approach to Portable Ontology Specifications". *Knowledge Acquisition*, 5(2):199-220, 1993.

Kalfoglou Y., Schorlemmer M. "Ontology mapping: the state of the art". *The Knowledge Engineering Review Journal*. 18(1), 1–31, 2003

Klein, M., "Combining and relating ontologies: an analysis of problems and solutions". In Gomez-Perez, A., Gruninger, M., Stuckenschmidt, H., and Uschold, M., editors, Workshop on Ontologies and Information Sharing, IJCAI'01, Seattle, WA.

Labrou Y., Finin T. "A proposal for a new KQML Specification", Internal Report TR CS-97-03, Computer Science and Electrical Engineering Department (CSEE), University of Maryland Baltimore County (UMBC), February 1997

Latif, K., Weippl, E.; A Min Tjoa. "Question Driven Semantics Interpretation for Collaborative Knowledge Engineering and Ontology Reuse" *in Proceedings of International Conference on Information Reuse and Integration*, IRI 2007. Las Vegas, 13-15 Aug. 2007 pp. 170 – 176

Noy N.F. "Semantic Integration: A Survey Of Ontology-Based Approaches", ACM SIGMOD Record, Vol. 33, n°4, December 2004

Olsen G.R., Cutkosky M., Tenenbaum J.M., Gruber T.R., "Collaborative Engineering based on Knowledge Sharing Agreements", *ASME Database Symposium, Minneapolis, 1994*

Sabou, M., d'Aquin, M., and Motta, E., "Using the Semantic Web as Background Knowledge for Ontology Mapping", in proceedings of International Workshop on Ontology Matching (OM-2006) at International Semantic Web Conference (ISWC'06).

Shvaiko P., Euzenat J., "Ten challenges for ontology matching" *in Proceedings of the 7th International Conference on Ontologies, DataBases, and Applications of Semantics* (ODBASE), 2008

Roche C., "Ontology: a Survey", *8th Symposium on Automated Systems Based on Human Skill and Knowledge*, IFAC, September 22-24 2003, Göteborg, Sweden

Roche C., "The *Specific-Difference* Principle: a Methodology for Building Consensual and Coherent Ontologies" *in Proceedings of International Conference on Artificial Conference (IC-AI'2001):* Las Vegas, USA, June 25-28 2001

Shvaiko P., Euzenat J. "ASurvey of Schema-Based Matching Approaches", Journal on Data Semantics IV, LNCS 3730, pp. 146-171, 2005.

Spies M. Roche C., "Aristotelian Ontologies and OWL Modeling", Handbook of Ontologies for Business Interaction, 2008, pp. 21-33

Ushold M., Gruninger M., "Ontologies : Principles, Methods and Applications". In: *Knowledge Engineering Review,* Vol. 11, n° 2, June 1996

WordNet, "WordNet: An Electronic Lexical Database", Edited by Christiane Fellbaum, MIT Press 1998.

BIOGRAPHY

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Identifying the right simulation data for project scheduling

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KEYWORDS
Project Management, Scheduling, Monte Carlo Simulation, Input Data.

ABSTRACT

Project scheduling is an important process within project management, providing an estimation regarding the duration of the project. Completion within the estimated duration is considered a crucial project success factor. In this concept, simulation is a valuable tool which overcomes most of the disadvantages of deterministic scheduling approaches and allowing a realistic modelling of project activity network and project duration. However, the quality of the results produced through simulation depends on the quality of the input data. This paper focuses on the identification of appropriate input data presenting an approach based on the acquisition of experts' knowledge through interviews and questionnaires.

1. INTRODUCTION

Project management success is usually measured against the four project objectives namely cost, time, scope and quality (Kerzner, 2003). Furthermore, even if a project is not, mainly, time-constrained, completing projects on time, generally, is an indicator of an efficient industry (Chan and Kumaraswamy, 1997). Thus, time has been in the centre of project management research for many decades. In a nutshell, *project time management includes the processes required to accomplish timely completion of the project* (PMBOK, 2004).

Schedule development defines tasks' durations as well as the right dependencies among project tasks. Unless this has been achieved, the project manager cannot determine the start and finish dates of project tasks. *The project is unlikely to finish on schedule if either the duration of activities or the definitions of dependencies are not realistic* (Diamantas et al., 2006).

This paper, as a continuum to previous research presented at previous FUBUTEC Conference (Diamantas et al., 2006), aims at providing an approach for defining stochastically the duration of activities before the data is entered in a simulation tool.

Specifically, the research is focused on the construction industry. Interviews based on a structured questionnaire were conducted in order to capture the tacit knowledge (Nonaka and Takeuchi, 1995) of twenty two civil engineers, contractors of small to medium projects, regarding approximately 50 tasks involved in construction, such as concrete works, brick works, plastering, etc. A detailed description of these tasks were given to responders and they were asked to estimate the optimistic, most probable and pessimistic duration for delivering one "measure unit" of each task.

The work experience of the civil engineers that took part in the research is presented in **Fig. 1**.

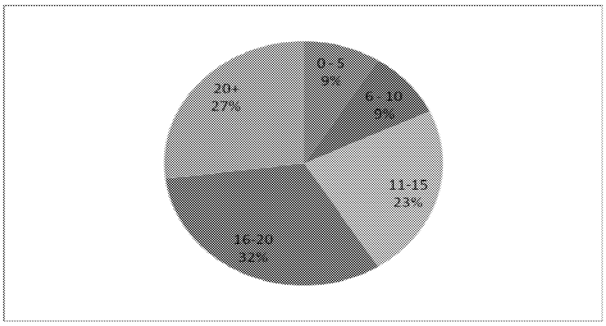


Fig. 1 **Work experience of participants**

The data collected for each task have been fitted to distributions with the use of a software tool. Vose (2000) defines fitting as a technique to interpret observed data for a variable in order to derive a distribution that realistically models its true variability and the uncertainty about that true variability.

The distributions provided by the interviews have been used as input data to Monte Carlo Simulation for the time duration estimation of a specific construction project case. After the execution of the project, the result of the Monte Carlo Simulation was compared to the actual duration in order to validate the initial distributions.

The overall outcome is very promising as most of the actual values of tasks durations resided within the initial distribution and the overall project duration resided within the Monte Carlo Simulation projection. Thus, one may come to the conclusion that gathering experts' knowledge with a systematic and structured approach may indeed help identifying the right simulation data for project scheduling.

2. Case Study

2.1 Description

The presented project is a three stories residential building located in an Athens' suburb. Specifically, the research focused on 31 activities, shown in the second column of **Table 1**, consisting the first phase of construction. Based on the stochastic duration of each task, as concluded from the interviews, a Monte Carlo Simulation was run for the whole project in order to be used as a duration estimation of the project.

The actual duration of the first phase of the project was 107 days.

2.2 Results

The distribution for the total duration of the first phase of the project, as calculated through simulation, is presented in **Fig. 2**. It is a Weibull distribution with a mean value of 104,41 days. The distribution graph closely resembles a normal distribution. However, this resemblance is coincidental and should not be considered expected in every project.

The actual duration of 107 days corresponds to a confidence level of 74,3% of the estimated Weibull distribution.

Detailed results regarding the estimation and actual duration regarding each project activity are presented in **Table 1**.

Further analysis of these results indicates that in 13 cases the absolute difference between the estimation and the actual duration is lower than 10%. In 10 cases the difference between the estimation and the actual duration is greater than 10% and lower than 20%, while in 8 cases the difference is greater than 20%.

In addition, in 7 cases the estimation is conservative (positive difference) while in the majority of the cases, 23 of them, the estimation is optimistic (negative difference). Only in one case does the estimation match the actual duration of the activity.

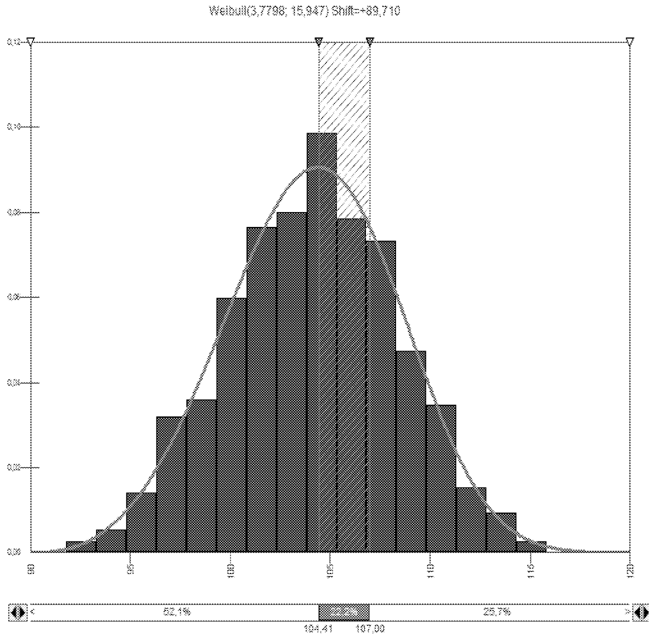
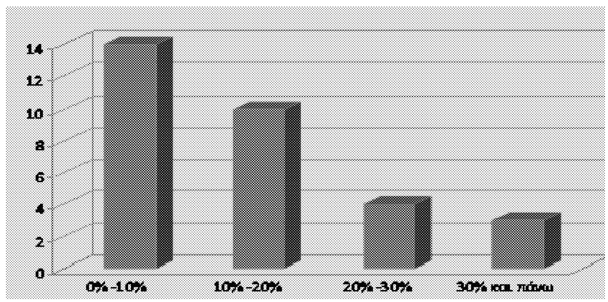


Fig. 2 Total Project Duration

Furthermore, in 2 cases the actual value corresponds to a confidence level lower than 0% and in 2 cases the actual value corresponds to a confidence level >100%.

3. Conclusion

Figure 3 sums up the information provided in the previous section indicating that the results from the initial questionnaire comply with real world problems.



Of course, one cannot draw a safe conclusion from just one case study, however, even this result is indicative that the whole process is on the right direction.

As further research the authors are already implementing the test cases to other projects aiming to validate the initial outcomes.

Table 1 Comparison between estimation and actual duration per activity

No	Activity	Difference Mean – Actual (%)	Corresponding Confidence Level of actual value (%)

No	Activity	Difference Mean – Actual (%)	Corresponding Confidence Level of actual value (%)
1	Foundation (Footings) - Woodwork	-25.33	95.1
2	Foundation (Footings) – Armament	0.33	55,2
3	Ground Floor Concrete Pier - Woodwork	-10.00	67.5
4	Ground Floor Concrete Pier - Armament	0.67	48.4
5	Ground Floor Slab - Woodwork	0.00	50.0
6	Ground Floor Slab - Armament	8.00	36.9
7	Level A Concrete Pier - Woodwork	-12.00	67.4
8	Level A Concrete Pier - Armament	-7.33	49.9
9	Level A Slab - Woodwork	-14.00	85.6
10	Level A Slab - Armament	-12.00	77.8
11	Level B Concrete Pier - Woodwork	-14.00	69.4
12	Level B Concrete Pier - Armament	-16.00	82.1
13	Level B Slab - Woodwork	-14.00	84.9
14	Level B Slab - Armament	-7.00	73.3
15	Blacktop placement	6.00	49.1
16	Dow placement	-18.00	54.8
17	Brickwork	-46.25	> 100
18	Mortat	-16.50	88.7
19	Aluminum temporary frames placement	32.80	< 0
20	Internal doors temporary frames placement	-23.00	93.8
21	Wiring pipes	173.00	< 0
22	Plumbing piping	-32.50	98.1
23	Drainage piping	-3.00	56.2
24	Heating piping	-53.60	> 100
25	Marble	-1.00	55.3
26	Roof – Wooden frame	-12.00	95.9
27	Roof – Insulation	-35.20	98.9
28	Roof – Clay roof tiles placement	-6.67	64.3
29	Plastering - basic layer	1.67	51.3
30	Plastering - second layer	-6.89	52.6
31	Plastering - finishing	-4.56	59.2

REFERENCES

Chan, D. and Kumaraswamy, M., 1997, "A comparative study of causes of time overruns in Hong Kong construction projects", *International Journal of Project Management* 15(1), 55-63.

Diamantas, V., Kirytopoulos, K. and Leopoulos V., 2006, "Simulation in Project Scheduling: Why PERT is not enough", *in Proceedings of the 3rd Future Business Technology Conference*, Athens, Greece, 17-19 April 2006, pp. 64-70.

Kerzner H., 2003, *A Systems Approach to Planning, Scheduling, and Controlling (8th ed.)*. Wiley & Sons.

Nonaka, I. and Takeuchi, H., 1995, *The Knowledge-Creating Company*, Oxford: Oxford University Press.

Project Management Institute, 2004, *A guide to the project management body of knowledge (PMBOK® Guide) (2004 ed.),* Project Management Institution, Newton Square, PA, USA.

Vose D., 2000, *Risk Analysis: A Quantitative Guide* (2ed). UK: Wiley.

COSTING

MINIMISING THE COST OF SCHEDULING MAINTENANCE TASKS ON A SINGLE MACHINE

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Branch and bound, single machine scheduling, valid inequalities.

ABSTRACT

This paper deals with the problem of scheduling maintenance tasks for a single processor. The considered maintenance tasks have some characteristics: when a maintenance task completes before a first due date d_{i1} or after a second due date d_{i2} , greater than d_{i1}, the cost of the maintenance is greater to that when the task i is achieved in [d_{i1} , d_{i2}] interval. In other words, the maintenance task's cost is considered optimal if and only if its completion time is in [d_{i1}, d_{i2}] interval. To solve optimally the problem, we develop in a first step a linear model. In a next step, we add to this model some valid inequalities in order to improve its linear relaxation objective function value and use it as lower bound in a branch and bound algorithm. Computational results are presented and analysed in the last part of this paper.

INTRODUCTION

Maintenance activities are characterized by a planning which depends on the failure distribution's law of a machine's components. For example, a production machine consists of different components. Sometimes the whole components follows the same distribution failure's law but with different parameters and sometimes each component has its own distribution failure's law.

For instance, a hydraulic cutting press has as componements a portico (main structure), a press table, an engine auctioneer, a translation axis, 2 landings with movements, a speed reducer, a drive belt, 2 hydraulic jacks, a hydraulic pump, a cutting matrix, a cutting knife, an electric power converter, an electronic control block, an automate (robot), sensors and mechanical and electric devices of safety and protection. Each of these components has a time interval between two actions of preventive maintenance, function of its degradation.

Preventive maintenance of this machine requires many actions made on each of its components in a sequence where the earliness and the tardiness must be controlled. Thus, it is necessary to check the dates of intervention on every component, represented by an interval [TM-Δt , TM+Δt] around the date TM which is estimated for a minimum failure risk.

Besides, an intervention made before the first deadline (TM-Δt) of this interval would increase pointlessly the preventive maintenance cost. This cost is proportional to the frequency of the interventions made before TM-ΔT. In another hand, when the intervention is placed after TM + ΔT, the preventive maintenance cost incurs from two ways: the decrease of the intervention's frequencies due to the length of the time intarval between 2 successive interventions, that generates a cost related to the greater risk of failure and the losses' cost due to the defective products which is function of the intervention's delay.

In this same context, we are interested in the problem of scheduling a set of maintenance tasks on a single machine. Each task has a processing time p_i, an early due date d_{i1} and a tardy due date d_{i2}. The running of the tasks on the machine is continuously during the period of maintenance.

When a task ends before its early due date d_{i1} or its completion time exceeds the tardy due date d_{i2} then its maintenance cost is greater than the optimal cost. However when the task ends between d_{i1} and d_{i2} then maintenance cost is considered optimal.

We suppose that the maintenance costs are linear according to the deviation between the maintenance task's completion time and the early due date and according to the deviation between the task's completion time and the tardy due date.

This paper is organized as follows. In Section II, we present the literature review related to our problem. In the section III, we develop in a first step a linear model and in a second step we add to this model new valid inequalities to improve its linear relaxation. In section IV, we provide a new upper bound. In section V, the implementation of the branch and bound algorithm is described. Computational results are discussed in section VI. Finally, we summarize the obtained results.

LITERATURE REVIEW

This section is devided in tow parts. The first part deals with maintenance in production plan. The second part deals with the problem of minimizing the early and tardy job's cost on a single machine.

In the literature, several articles treating simultaneously the problem of maintenance and production. For example, Lee et al [8] considered in their work the problem of scheduling a set production tasks that must be made on a park of the machines where every machine must be once maintained during the horizon of production. The objective is to determine a schedule for the production tasks and the maintenance activities so that the total weighted jobs completion times of jobs is minimized. Two case are studied.

In the first case many machines can undertake maintenance operations at the same moment due to the sufficient resources. In the second case just one machine can take on maintenance. Both cases are shown NP-hard and solved by a branch and bound algorithm based on column generation approach. Results show that the branch and bound algorithms are capable of optimally solving medium sized problems within a reasonable computational time.

Graves et al [5] have studied the problem of scheduling a set of jobs on a single machine where the machine must be under maintaince in certain intervals. Thus, it is not available during these periods. When a job is not completely handled before the machine is turned off for maintenance, a setup time is necessary when the treatment is taken back. Two objectives were considered: the minimization of the total weighted jobs completion time and the minimization of the maximum delay. The problem is solved by the dynamic programming approach.

Aghezzaf and al [4] were interested in the batch production problem. The production system is subject to random failures and at each maintenance intervention the production system is not available which decreases its production capacity. The purpose of their study was to determine a plan in which the cost of production maintenance is minimal. The problem is solved by a linear model.

Now we limit this part of section to the works treating the minimization of total earlyness and tardiness cost without considering the preemption of jobs and the machine idle time.

The first remarkable work was proposed by Held and Karp [3]. These authors proposed a dynamic programming approach for solving the problem in which all the states correspond to a subset of jobs and the recursion consists in adding a task in passing from a state to the other one.

Azizoglu et al. [1] proposed a branch and bound algorithm for the $1|d_i|\sum w_iT_i + h_iE_i$ problem. The lower bound is obtained by the relaxation of the variable completion time (Ct) in the model and the upper bound is determined by local search technique used in two levels: in a first level α jobs are selected and an upper bound is determined by sequencing the remaining jobs according to the EDD rule. β partials sequences having the minimal upper bounds will be chosen. In the second level, every sequence obtained will be completed by one of the α jobs. Among $\alpha\beta$ partial sequences the best β will be selected for another evaluation.

The procedure is repeated until the sequence β will be completed. Other sequences are also generated by priority rules.

The sequence having the minimal evaluation among all sequences will be the upper bound.

Results show that the upper bound is slightly superior to the optimal solution produced by the branch and bound algorithm.

George Li [5] used a B&B algorithm to solve short sequences (< 50 jobs). This algorithm based on a neighbourhood search heuristic and a lower bound determined by decomposing the main problem into two sub-problems and solving their Lagrange duals.

Indeed, the main problem $(1|d_i|\sum w_iT_i + h_iE_i)$ is decomposed into two sub problems $(1|d_i|\sum w_iT_i)$ and $(1|d_i|\sum h_iE_i)$. Each of these sub problems is formulated by a linear model for which a constraint is relaxed. By solving the two Lagrange duals problems by the adjustment multiplier approach, we obtain two lower bounds.

The lower bound of the main problem is obtained by summing the two obtained lower bounds.

Computational results indicate that the B&B algorithm can easily produce optimal solutions for problems of small size. The results also show that local search heuristic is not only effective, but also strong.

Liaw [6] also proposed a B&B algorithm to handle the problem of $(1|d_i|\sum w_iT_i + h_iE_i)$. The upper bound of the algorithm is obtained by calculating in a first step an initial solution by the priority rule of Ow and Morton [9]. In the second step, the initial solution will be improved by an insertion procedure followed by a permutation procedure.

The lower bound is obtained by the decomposition of the main problem relaxed in two sub-problems and the calculation of a lower bound for one of sub-problems. The lower bound of the main problem will be improved by using the Lagrange multipliers of the sub-problem already solved in the second sub-problem. The obtained results show that the B&B algorithm is very effective even for problems of 50 jobs.

M'Hallah [7] solves the single machine earliness–tardiness scheduling problem by hybridizing Genetic Algorithm with Hill Climbing and Simulated Annealing using the two levels of hybridization: the low level and the high level. In the low level teamwork hybridization, she increases the ability of Genetic Algorithm to perform a local search by replacing its classical mutation operator by Hill Climbing; and in the high level relay hybridization; she acts both on the initial population and on the best individuals of each generation.

She uses three greedy heuristics to generate the initial population, and refine the best solutions of each generation using Simulated Annealing.

Sourd et al [10] propose recently a branch and bound based on a lagrangian relaxation of the constraints of resources in a time indexed formulation and they add new rules of dominance allowing solving problems of size of 50 jobs.

Several other researchers developed other version of this problem by adding machines or considering the case with a common non-restrictive due date [9].

LINEAR MODEL

Standard formulation:

$$Min \sum_{i=1}^{N} \hat{C}_i$$

S / C

$$C_i + d_i^- - d_i^+ \geq d_{i1} \quad \forall i = 1...N \quad (1)$$

$$C_i + d_i^- - d_i^+ \leq d_{i2} \quad \forall i = 1...N \quad (2)$$

$$\hat{C}_i = \alpha_1 d_i^- + \lambda_{i1}\hat{C}_{i1} + \lambda_{i2}\hat{C}_{opt} + \alpha_2 d_i^+ + \lambda_{i3}\hat{C}_{i2} \quad \forall i = 1...N \quad (3)$$

$$\lambda_{i1} + \lambda_{i2} + \lambda_{i3} = 1 \quad \forall i = 1...N \quad (4)$$

$$d_i^- + P(1 - \lambda_{i1}) \geq 1 \quad \forall i = 1...N \quad (5)$$

$$d_i^- - P\lambda_{i1} \leq 0 \quad \forall i = 1...N \quad (6)$$

$$d_i^+ + P(1 - \lambda_{i1}) \geq 1 \quad \forall i = 1...N \quad (7)$$

$$d_i^+ - P\lambda_{i3} \leq 0 \quad \forall i = 1...N \quad (8)$$

$$\sum_{i=1}^{N} x_{ij} = 1 \quad \forall j = 1...N \quad (9)$$

$$\sum_{j=1}^{N} x_{ij} = 1 \quad \forall i = 1...N \quad (10)$$

$$C_i + P(1 - x_{ij}) \geq \sum_{i=1}^{j} \sum_{t=1}^{N} p_t x_{it} \quad \forall i = 1...N \quad \forall j = 1...N \quad (11)$$

$$C_i - P(1 - x_{ij}) \leq \sum_{i=1}^{j} \sum_{t=1}^{N} p_t x_{it} \quad \forall i = 1...N \quad \forall j = 1...N \quad (12)$$

$$x_{ij} \in \{0,1\}$$

$$P = \sum_{i=1}^{N} p_i \qquad C_i \in N$$

$\hat{C}_i$: is the assignement cost of job *i*

d_{i1} : is the early due date of job *i.*

d_{i2} : is the tardy due date of job *i.*

d_i^+ : represent the tardiness of job *i* when it is tardy.

d_i^- : represent the earliness of job *i* when it is early.

C_i : is the completion time of job *i*.

$$\lambda_{i1} \begin{cases} 1 \text{ if job } i \text{ is early.} \\ 0 \text{ otherwise} \end{cases}$$

$$\lambda_{i2} \begin{cases} 1 \text{ if job } i \text{ is on time.} \\ 0 \text{ otherwise.} \end{cases}$$

$$\lambda_{i3} \begin{cases} 1 \text{ if the job } i \text{ is tardy.} \\ 0 \text{ Otherwise.} \end{cases}$$

$$x_{ij} \begin{cases} 1 \text{ if the task } i \text{ is assigned to position } j. \\ 0 \text{ Otherwise.} \end{cases}$$

$\hat{C}_{i1} = c_0$: represent the constant cost part when task *i* is early.

$\hat{C}_{i2} = c_1$: represents the constant cost part when task *i* is tardy.

$\hat{C}_{opt}$: represents the optimal maintenance cost.

Constraints (1) and (2) decides for every task to be early, tardy or on time in the optimal sequence.

Constraint (3) determines the optimal cost for every task.

Constraints (4), (5), (6), (7), (8) allow for each task to take just a single cost (earliness cost, optimal cost or tardiness cost).

Constraints (9) and (10) are assignment constraints: they indicate that every task must be necessarily assigned to a single position and a position has to contain only a single task.

Constraint (11) calculates completion time of the task *i* when it is tardy in its optimal position.

Finally the constraint (12) determines the completion time of the task *i* when it is early in its optimal position.

Valid constraints:

In this section we try to add to the last model some new constraints in order to improve its linear relaxation.

Definition 1:

Let $\alpha = (\alpha_1, \cdots, \alpha_N)$ and $\beta = (\beta_1, \cdots, \beta_N)$ be tow vectors of positive numbers and $p = (p_1, \cdots, p_N)$ be the vector of processing times. Let $WF_1(p, \alpha)$ denotes the minimal weighted flow-time obtained by applying the $WSPT$ rule (proposed by Smith) to the corresponding problem $1|\,|\sum \alpha_i C_i$ and $WF_2(p, \beta)$ denotes the maximal weighted flow-time obtained by applying the $WLPT$ rule.

Property1(Kacem[5]). et $\alpha = (\alpha_1, \cdots, \alpha_N)$ be a vector of positive numbers. Therefore, the following inequality holds:

$$\sum_{i=1}^{N} \alpha_i C_i \geq WF_1(p, \alpha)$$

$$\sum_{i=1}^{N} \alpha_i C_i \leq \sum_{i=1}^{N} \alpha_i (P - p_i) - WF_1(p, \alpha)$$

Property 2. Let $\beta = (\beta_1, \cdots, \beta_N)$ be a vector of positive numbers. Therefore, the following inequality holds:

$$\sum_{i=1}^{N} \beta_i C_i \leq WF_2(p, \beta)$$

$$\sum_{i=1}^{N} \beta_i C_i \geq \sum_{i=1}^{N} \beta_i (P - p_i) - WF_2(p, \beta)$$

Definition 2:

Let $\underline{C}_{ij}$ be a lower bound on the completion time of the task *i* assigned to position *j* in the optimal sequence calculated according the following formula:

$$\underline{C}_{ij} = \max \; (\underline{C}_{ij}^1, \underline{C}_{ij}^2)$$

$$\text{Where} \begin{cases} \underline{C}_{ij}^1 = \sum_{k=1}^{j} p_{[k]} \text{ if } i \in \{ [1], [2], ..., [j] \} \\ \underline{C}_{ij}^2 = \sum_{k=1}^{j-1} p_{[k]} + p_i \text{ if } i \notin \{ [1], [2], ..., [j] \} \end{cases}$$

$[k]$ is the k^{th} task in the sequence *S* obtained by the *SPT* rule.

Therefore, the following inequality holds:

$$C_i \geq \sum_{j=1}^{N} \underline{C}_{ij} x_{ij} \quad \forall i = 1...N$$

Definition 3:

Let $\overline{C}_{ij}$ be an upper bound on the completion time of job *i* assigned to position *j* in the optimal sequence calculated according the following formula:

$\overline{C}_{ij} = \min \ (\overline{C}_{ij}^1, \overline{C}_{ij}^2)$

Where $\begin{cases} \overline{C}_{ij}^1 = \sum_{k=1}^{j} p_{[N-k+1]} & \text{if } i \in \{ [N],[N-1],...,[N-j+1] \} \\ \overline{C}_{ij}^2 = \sum_{k=1}^{j-1} p_{[N-k+1]} + p_i & \text{if } i \notin \{ [N],[N-1],...,[N-j+1] \} \end{cases}$

Therefore, the following inequality holds:

$C_i \le \sum_{j=1}^{N} \overline{C}_{ij} x_{ij} \qquad \forall i = 1 \dots N$

Property 3. Let $p = (p_1, \cdots, p_N)$ be the vector of processing times. Therefore, the following equality holds:

$\sum_{i=1}^{N} p_i C_i = \sum_{i=1}^{N} p_i C_i^H$

Where C_i^H represents the completion time of job i in an arbitrary solution.

BRANCH AND BOUND ALGORITHM

In this section we briefly define the three main procedures that are involved in any branch and bound algorithm: the initialization, the branching and the bounding.

Initialization:

During this step, an initial complete solution is found until a better solution is obtained. This initial solution represents an upper bound. Any node with a lower bound greater than the upper bound is eliminated. The upper bound proposed in this paper is based on the neighbourhood search approach.

In this neighbourhood search approach eight initial schedules are produced. The first one is obtained by the application of the *SPT* rule to the jobs. The second one by the application of the *LPT* rule, the third one by the application of the *WSPT* rule, the fourth one by the application of the *WLPT* rule, the fifth one using the early/tardy dispatch priority rule developed by Ow and Morton [9], the six one by the application of the EDD according d_{i1} and the seven one according d_{i2}. Finally, the last solution is obtained by scheduling the tasks according the increasing order of $(d_2 - d_1)$.

The upper bound is determined as follows:

First, we begin evaluate the eight determined solutions and we fix the value of the upper bound to the best found evaluation. Then, for each solution, we determine a neighbourhood by applying a series of transformation. These transformations consist of some permutations of tow tasks having *h* jobs between them *(h=0...N-1)*. At each transformation, the new solution obtained is evaluated and the value of the lower bound is usually improved when an evaluation of a new schedule is less than the current lower bound's value.

Branching:

Branching is the procedure used to develop the search tree. In this paper we adopt the depth first strategy with a backward sequencing branching rule, where a node at level *k* of the search tree corresponds to a sequence with *k* jobs fixed in the *k* last positions.

Bounding:

Bounding means determining a lower bound for a partial sequence S_p in a node of the tree search. The lower bound described above is the lower bound used in the tree search. To more improve the performance of the lower bound, we used a dominance property that consists of comparing two partial schedules: The first schedule corresponds to the partial fixed sequence in the node and the second is obtained by exchanging the two last jobs in the first sequence. When the evaluation of the first partial sequence is greater than the second, we stop the separation in the node. Otherwise we add to the node the corresponding remaining tasks.

COMPUTATIONAL RESULTS

The branch-and-bound algorithm was tested on problems with 7, 10, 13, 15 and 18 jobs that are generated as follows: For each job *i*, we firstly assign to the maintenance cost C_{opt} an integer from the uniform distribution $[10..100]$ and to the processing time p_i an element from the uniform distribution [1, 100]. Secondly we add the tow fixed maintenance costs $\hat{C}_{i1}$ and $\hat{C}_{i2}$ that are integers from the uniform distribution $[1..C_{opt}/2]$. Then, an integer tardiness weight w_i and an integer earlyness weight h_i are generated from the uniform distribution $[C_{opt} \cdots C_{opt} + 10]$.

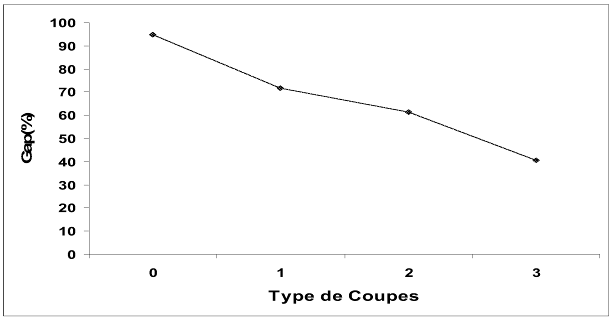
Finally, an integer from the uniform distribution $[P(1-T-R/2, \ P(1-T-R/2)]$ is assigned to the early due date d_{i1} and an integer from the uniform distribution $[d_{1i}, d_{1i} + 2P/3]$ is assigned to the tardy due date d_{i2}.

($P = \sum_{i=1}^{N} p_i$,$T \in \{0, 0.2, 0.6, 0.8, 1\}$ *and* $R \in \{0.2, 0.4, 0.6, 0.8\}$.)

T *:* is the average tardiness factor and R is the relative range of due dates.

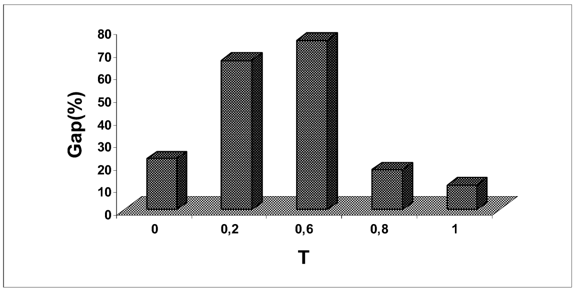
For each combination of *N, T* and *R*, 5 problems are generated; yielding 100 problems for each value of *N* are solved. The algorithm is coded in the *C* language and implemented on a Pentium IV-500 personal computer. To prevent excessive computation time, whenever a problem is not solved within the time limit of 3600 s (1h), the computation is stopped for that problem.

Results concerning the effect of adding valid constraints to the model are represented in figures 1 and 2. The percentage of average deviation of the upper bound (UBD), the percentage of average deviation of the lower bound (LBD), the average time to obtain the optimal solution (AT) and the average number of fathomed nodes in the search tree (AN) are presented in table 1.



Figures 1: Impovement of the lower bound by
the adding constarints

According to figure 1, we can notice that at each addition of a valid inequality type corresponds an improvement of the lower bound's value. This improvement is more important by the addition of the first type constraints and the third type. However it is less important by the addition of the second type.



Figures 2: Gap of the lower bound for the
different value of T

Figure 2 shows that the lower bound is more efficient when $T \in \{0, 0.8, 1\}$. For these value of T the gap is between 10% and 25%. For the remaining value the gap is between 70% and 80%.

Table 1: Implementation of the branch and bound

N	UBD(%)	LBD(%)	AN	AT(s)
7	0,7	39,54	19	0,26
10	2,35	40,18	119	3,11
13	3,4	35,65	2869	47,27
15[a]	3,72	35,34	4751	223,41
18[b]	3,61	31,2	10523	633,24

[a,b] : Indicate respectively that 10 and 31 instances are not solved on 1 hour.

The results in table 1 show that the proposed upper bound produces good initial solution having an average percentage deviation of 2,75 % from the optimal solution. The results also show that the lower bound has an average deviation of 36,38 % from the optimal solution.

We note that the computation of the lower bound requires computational time which depend on the size of the problem.

CONCLUSION

In this paper, we have solved the problem of scheduling a set of maintenance tasks on a single machine with the objective of minimizing the maintenance cost. Our method consists in a branch-and-bound procedure. The obtained results show that the upper bound produces initial solutions of a good quality while the lower bound has an average deviation of 36,38 % from the optimal solution after the addition of a set of constraints. We note that it is possible to improve the performance of the branch-and-bound algorithm through the dominance properties on the tasks.

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REFERENCES

[1] Azizoglu M, Kondakci S, Kirca O. Bicriteria scheduling problem involving total tardiness and total earliness penalties. International Journal of Production Economics 1991; 23.

[2] Baker KR, Scudder GD. Sequencing with earliness and tardiness penalties: a review. Operations Research 1990; 38(1): 22-36.

[3] C.-Y. Lee and Z-L.Chen. Scheduling Jobs and Maintenance Activities on Parallel Machines. *Naval Research Logistics*, Vol. 47 (2000).

[4] E.H. Aghezzaf, A. Jamali, D. Ait-Kadi, An integrated production and preventive maintenance planning model. European Journal of Operational Research 181 (2007) 679-685.

[5] G.H. Graves and C.-Y. Lee, Scheduling maintenance and semiresumable jobs on a single machine, Working Paper, Department of Industrial Engineering, Texas A&M University, College Station, 1998.

[6] Held M, Karp RM. A dynamic programming approach to sequencing problems. Journal of the Society for Industrial and Applied Mathematics1962; 10: 196–210.

[7] Kacem I. Lower bounds for tardiness minimization on a single machine with family setup times. International journal of Operations Research, 2007; 4 (1): 18-31.

[8] Li G. Single machine earliness and tardiness scheduling. European Journal of Operational Research 1997; 546–558.

[9] Liaw CF. A branch and bound algorithm for the single machine earliness and tardiness scheduling problem. Computers & Operations Research 1999; 26: 679-693.

[10] M'Halla R. Minimising total earliness and tardiness on a single machine using a hybrid heuristic. Computers & Operation Research 2006; 34: 3126 – 3142.

[11] Ow PS, Morton ET. The single machine early/tardy problem. Management science 1989; 35: 331-342.

[12] Rebai M, Kacem I. Minimizing the earliness-tardiness costs on a single machine. ICSSSM'08 conference.

[13] Sakib A. M, Anup K. S. Single machine weighted earliness/tardiness penalty problem with a common due date. Computers & Operation Research 2001; 28: 649 – 669.

[14] Sourd F, Keded-Sidhoum S, Rio Solis Y. Lower bounds for the earliness-tardiness scheduling problem on parallel machines with distinct due dates. European Journal of Operational Research 2007.

COST MODEL FOR PARTS SUPPLY IN AUTOMOTIVE INDUSTRY

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KEYWORDS
Facility logistics, material flow, kitting, cost model.

ABSTRACT

In practice, kitting, sequencing and downsizing are already found in a lot of production organizations. Nevertheless, considerable uncertainty still exists concerning the costs and benefits of these supply methods. The purpose of this research is to uncover the advantages and disadvantages of the different line feeding alternatives and quantify them. The complete flow of components, starting from the supplier to the supply at the final assembly line will be considered. Different methods of line feeding have an impact on material handling costs, operator efficiency, storage space requirement and flexibility. A cost model is developed that captures all these impacts and that quantifies the costs for different line feeding alternatives. This model is tested with data and some conclusions are drawn.

INTRODUCTION

For production to take place it is of a crucial importance to have the right materials, at the right time, at the right place, and in the exact amount. Therefore, in a manufacturing environment, a reliable process for supplying parts to an assembly line is indispensable.

Three main methods of line feeding are found in practice:

Bulk Line Feeding

Feeding a line in bulk means that no parts are yet assigned to a certain end product when they are delivered to the line. No logical combinations are made between the parts and each SKU is delivered in a full container quantity.

Downsizing

When full component containers can not be placed next to the line because of space restrictions, components can be repackaged in smaller containers or boxes.

Kitting/Sequencing

Kitting is the practice of putting together a kit of components and/or subassemblies – according to a future assembly schedule – before delivery to the shop floor. Kit assembly takes place in a separate supermarket area and kits can be delivered to the line in bulk kit containers or in sequenced kit containers.

Bulk Kit Containers
Supplying kits in bulk means that identical kit compositions are used regularly and the assortment of kit compositions is limited. Then for each specific kit a full container will be placed next to the line.

Sequenced Kit Containers
If in contrast the assortment of kit compositions is very broad and identical kit compositions are barely encountered, then it is not possible to put a full container of each specific kit at the line. Instead a container next to the line will consist of different kit compositions that are already correctly sequenced in accordance with the production schedule.
As kits can be sequenced, single parts can also be sequenced on a trolley or in a container. We designate no new category for this because it can be seen as a sequence of kits where the kit consists of only one part.

If bulk feeding is replaced with one of the alternative parts supply methods additional material handling needs to be done. This additional material handling can be done in a centralized supermarket or in decentralized kitting areas near the line.

Aside from the choice between these line feeding methods, companies also need to think about the insourcing/outsouring decision. The material handling activity of kitting, sequencing and downsizing can be done in-plant or it can be outsourced to a third party logistics provider or to the supplier. Therefore this study will take into scope the complete logistic flow of parts starting from the supplier and ending at the use-point at the production line.

This paper deals with the logistics costs these line feeding decisions bring about. Cost formulas are developed to get insight in the consequences of choosing a certain method of line feeding.

LITERATURE REVIEW

Although different line feeding methods are already found in practice for a long time, literature is rather limited. Some

literature focuses on practical issues concerning the implementation of kitting and sequencing.
The problem of allocating a limited amount of available components to different kits that demand the same components is extensively studied (Chen and Wilhelm 1993; 1994; 1997; Chen 2003). The problem is extended with additional assumptions of parts being substitutable and linked substitution. All of the models are developed to minimize total costs – including job earliness, job tardiness, and in-process holding costs.
The influence of uncertainty on kitting is also scrutinized. Choobineh and Mohebbi (2004) look at the positive effect of component sharing on kit availability, given variability in the procurement lead times of the components, or a varying demand. More theoretical derivations were shown about the work-in-process and the output of kitting operations that are afflicted with uncertain inputs (Som et al. 1994; Ramachandran and Delen 2005)
De Souza et al. (2008) propose a model for deciding how to pack the necessary items in the available containers. The model strives to minimize holding and handling costs.

Brynzer and Johansson (1995) discuss a number of case studies in order to get more insight in the design of kitting systems and the influence on performance. Some issues discussed are the location of the kitting system, the work organization behind the kitting operation, the relevance of a batching policy for picking the kits, the need for zone picking and the type of picking information used.

All above literature focuses on selected issues when a method of line feeding is chosen. However, we are interested in models covering the influence of different line feeding methods on the whole in-plant logistic system, in order to detect the most cost efficient organization. Little literature describes the development of a decision model (Bozer and McGinnis 1992; Carlsson and Hensvold 2008; Caputo and Pelagagge 2008). Bozer and McGinnis propose an evaluation model in order to compare kitting with line stocking. The performance measures used are the following: the necessary storage and retrieval of component containers, the flow of component and kit containers, the shop floor space requirements, and the average work-in-process. Carlsson and Hensvold adapt the model of Bozer and McGinnis and apply it to a real situation. To optimize for the multiple criteria, they use an Analytic Hierarchy Process technique. Further elaborations of the model are done by Caputo and Pelagagge. They distinguish between line-stocking, kitting and Kanban-based supply. Moreover they also consider hybrid policies. They convert part of the performance measures in a monetary value, i.e. investment costs, labor costs and WIP costs. However they still retain non-monetary performance measures and the model remains a multiple criteria decision making problem.

MODEL

A cost model is developed to capture the advantages and disadvantages of the different line feeding alternatives. The model is developed within the scope of the vehicle industry. The reason is that parts handling is a hot topic in the vehicle industry. More and more variation in the assortment is demanded and custom-made products are often requested. This trend leads to an increased amount of parts moving around on the shop floor and a lot of money is involved. In the vehicle industry parts are often large and voluminous and kitting is mainly done when there is a shortage of space next to the line and stocking full component containers of each individual SKU is not possible. However the choice of parts to be kitted is made on a very intuitive way by production engineers and no clear assessment can be made because of a lack of knowledge about the different line feeding methods and their impact.

The flow of parts that is taken into consideration by the cost model is starting at the parts supplier and ends at the final use point at the assembly line. Figure 1 shows a flowchart of the parts supply process. Material handling activities like kitting and sequencing can be done at the supplier, at a third party logistics provider (3PL) or at the original equipment manufacturer (OEM).

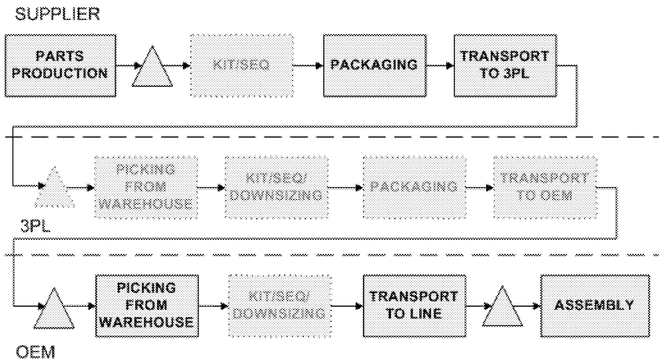

Figure 1: Parts Supply Process

The cost model is developed for five alternative parts supply flows:

1. Bulk feeding
2. Centralized kitting at the OEM
3. Decentralized kitting at the OEM
4. Kitting at the supplier
5. Kitting at a 3PL

The cost formulas cover the impact the different line feeding methods have on personnel cost, equipment cost, operating cost and WIP cost. All costs cover a period of one day. We will describe here how these costs are calculated.

General notation

We will first present the general notation we used throughout the formulas. We tried to organize the notation in logical blocks in order to increase the readability.

D number of end products produced in an 8 hour day

m_s number of pieces of SKU s used in one unit of the end product (or in one kit)

p_s number of pieces of SKU s stored in a component container

p_k number of pieces stored in a kit container type k

COT operator cost
COH cost of operator per hour (logistic operator, production operator or driver)
Tos_s average operator time (h) for doing an action on a unit of SKU s
Toc average operator time (h) for doing an action on a component container or kit container
Tob average operator time (h) for doing an action on a batch of component containers or kit containers
Noc number of component or kit containers an operator can handle at the same time

CET energy consumption cost
CEH cost of energy consumption per hour
Tms_s average machine time (h) for doing an action on a unit of SKU s
Tmc average machine time (h) for doing an action on a component container or kit container
Tmb average machine time (h) for doing an action on a batch of component containers or kit containers
Nmc number of component or kit containers a machine can handle at the same time

CCF daily floor investment capital cost
CBM building cost per month
APB occupied percentage of the building area
N number of working days per month
n number of working hours per day
CCE daily equipment investment capital cost
CMM machine cost per month

CCM capital cost of work in process
I_s average inventory level
P_s price of SKU s
C cost of capital

Two general new variables are constructed:

c_s total number of component containers of SKU s to be supplied to the workstation per 8 hour day

$$c_s = D * \frac{m_s}{p_s}$$

Each SKU will only account for a proportional part of the costs for handling a kit, therefore we create a second variable:

c_s^k SKU s proportion of the total number of kit containers of type k to be supplied to the workstation per 8 hour day

$$c_s^k = D * \frac{m_s}{p_k}$$

Labor cost formulas (personnel)

Labor costs include the costs of logistic operators, production operators and drivers.

Logistic operators do material handling activities like warehouse picking, loading and unloading of trucks, packaging, additional material handling activities like kitting, downsizing and sequencing and they carry out the internal transport to the line. Production operators are responsible for assembly. Although assembly itself is not taken into scope, the time for picking parts from the line stock is included. Drivers do the transport between the different players, i.e. the supplier, the third party logistic provider and the OEM.

The total operator cost can be calculated as:

$COT =$ operations on SKUs + operations on containers + operations on batches of containers

$$COT = D * m_s * Tos_s * COH + c_s * Toc * COH + c_s * \frac{Tob}{Noc} * COH$$

When we are dealing with kit containers c_s needs to be replaced by c_s^k.

Operating cost formulas

Operating costs include energy consumption costs for the equipment that is used. Equipment comprises material handling equipment, tools the operator uses at the line and trucks for transporting the components.

The total energy consumption cost can be calculated as:

$CET =$ operations on SKUs + operations on containers + operations on batches of containers

$$CET = D * m_s * Tms_s * CEH + c_s * Tmc * CEH + c_s * \frac{Tmb}{Nmc} * CEH$$

When we are dealing with kit containers c_s needs to be replaced by c_s^k.

Equipment cost formulas

Equipment costs include the investment costs of buildings for storage or production space, the investment costs of material handling equipment or rental costs and the investment cost for trucks.

$$CCF = CBM * \frac{APB/100}{N}$$

$$CCE = \frac{CMM}{N * n} * c_s * \frac{Tmb}{Nmc}$$

When we are dealing with kit containers c_s needs to be replaced by c_s^k.

Work in process cost formulas

Work in process (WIP) requires not only storage space but it also represents capital investment and presents a risk of expiration of the goods. We will not deal with expiring goods but we will include the capital cost of work in process in our model.

$$CCM = I_s * P_s * \frac{C}{12 * N}$$

APPLICATION AND RESULTS

The cost calculator is evaluated by inputting some test data. The component dealt with in the test case has the following characteristics:

$$D = 15$$
$$m_s = 1$$
$$p_s = 300$$
$$p_k = 5$$
$$P_s = 8.45$$

Two scenarios are inputted, i.e. bulk feeding on the one hand and kitting at the OEM in a centralized supermarket.

The output of the cost calculator is given in Figure 2.

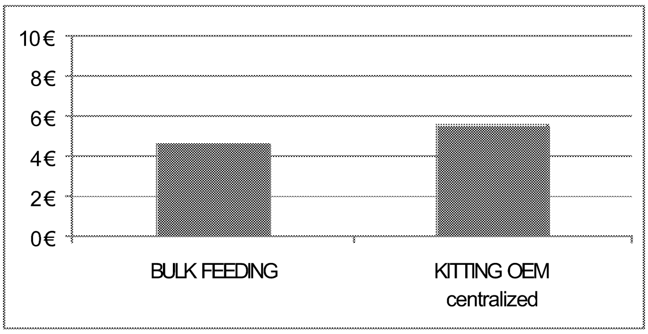

Figure 2: Output base case – Total costs

The recommendation is to bring the component to the line in bulk.

Moreover the output of the cost calculator shows how the total costs are distributed over the four sub categories, i.e. labor, operating, equipment and work in process (Figure 3).

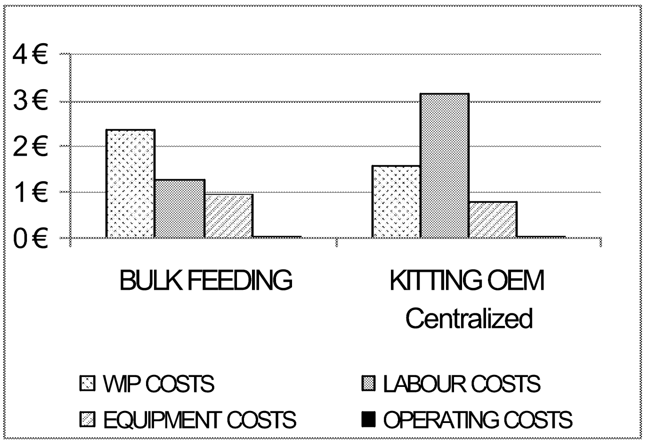

Figure 3: Output base case – Detail costs

On the one hand we see that WIP costs decrease when the component is kitted. This is because the stock at the line is minimized. Labor costs, operating costs and equipment costs on the other hand increase because kitting requires a lot of material handling and extra space for a supermarket area.

We can now change some characteristics of the case to get more insight into the problem. For example, if we increase the price of the component we will see that there is a breakpoint around €18 (Figure 4). If the component becomes more expensive, kitting will become the preferable supply method. This breakpoint can be understood intuitively as the price will have an influence on the work in process cost. The more expensive a component is the larger will be the advantage of a reduced stock when the component is kitted.

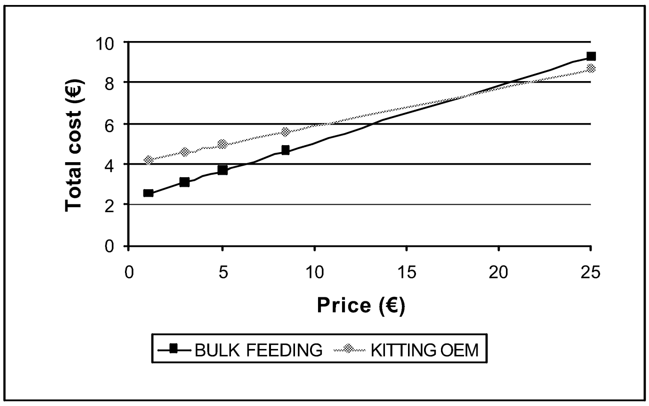

Figure 4: Change of price P_s

Another input characteristic that can be changed and will have an influence on the cost output and the preferred supply method is the distance to the line. If the warehouse is located closer to the assembly line, kitting will be more likely preferred. If we halve the average times of transportation we notice that the breakpoint price will go down from €18 to €8,5 (Figure 5). The same effect can be obtained when the distance remains the same, but when the transportation mode is twice as efficient. In this case CEH will decrease.

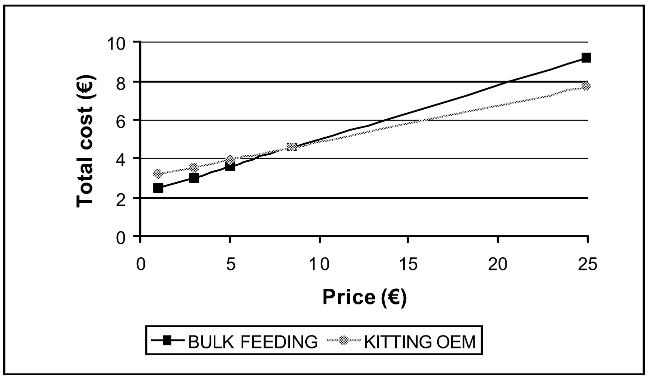

Figure 5: Change of price P_s – warehouse closer to the line

The value of p_s – the number of pieces in a component container – also influences the output decision. If the value of p_s decreases from 300 to 250 the breakpoint price will go up from €18 to around €22,5 and kitting will be less preferable (Figure 6). The reason behind this is that the advantage in work in process that kitting has over bulk feeding will be less outspoken.

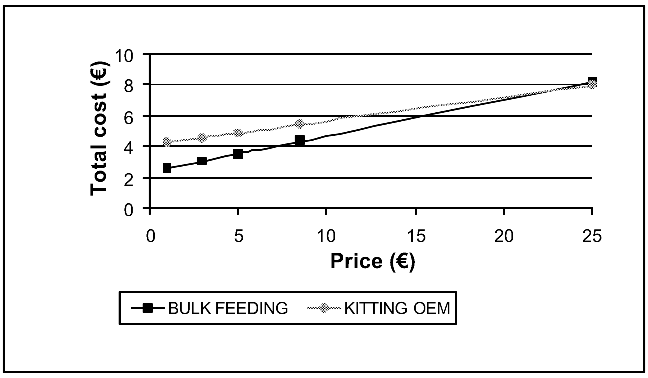

Figure 6: Change of price P_s – smaller component containers

The results presented above are only preliminary results. More testing is required to get more insight into the influence factors and the interactions that will occur.

CONCLUSIONS AND FURTHER RESEARCH

The cost model will need to be refined in the course of further research. First of all the cost formulas need to be validated and improved. This model is a first draft but additional research is necessary to refine the transfer functions. For now we only have included linear transfer functions but we believe that it may be necessary to include nonlinearities in the model.

Secondly, an additional factor we want to take into scope is the impact of error proofing and end-product quality. Kitting has a large influence on error proofing. When the kitting activities are done in a warehouse or supermarket environment – i.e. not by the operator at the line – more developed methods of error proofing as pick-to-voice and pick-to-light can be put in place. These methods will assure that the operator at the line receives an errorless kit without having to search for the correct parts. This will result in the end in more qualitative end products.

The downside of kitting however is the lack of safety stock at the line. Although the probability of having an error in a kit can be minimized by using appropriate error proofing techniques, material can be still be damaged and unusable. In this case a recovery time needs to be taken into account and a cost of delay will be encountered.

In the end we want to cover all possible material supply flows with our model. We recognize a lot of variants because not only can one choose for different supply methods, different internal transportation modes are also possible; kitting can be organized in different ways; kitting can be done by different supply chain players; the kit batch size can differ; transport can be done in milk runs or Kanban-based; etc.

During the development of the model sensitivity tests can be done to get a better understanding of the problem. Input parameters can be changed to get insight about which kind of parts and in which situation are to be supplied to the line by which line feeding method to proceed in a cost efficient mode.

REFERENCES

Bozer, Y.A. and L.F. McGinnis. 1992. “Kitting versus line stocking.” *International Journal of Production Economics*, 28, 1-19.

Brynzer, H. and M.I. Johansson. 1995. “Design and performance of kitting and order picking systems.” *International Journal of Production Economics*, 41, 115-125.

Chen, J.F. and W.E. Wilhelm. 1993. “An evaluation of heuristics for allocating components to kits in small-lot, multi-echelon assembly systems.” *International Journal of Production Research*, Vol. 31, No. 12, 2835-2856.

Chen, J.F. and W.E. Wilhelm. 1994. “Optimizing the allocation of components to kits in small-lot, multi-echelon assembly systems.” *Naval Research Logistics*, 41, 229-256.

Chen, J.F. and W.E. Wilhelm. 1997. “Kitting in multi-echelon, multi-product assembly systems with parts substitutable.” *International Journal of Production Research*, Vol. 35, No. 10, 2871-2897.

Chen, J.F. 2003. “Component allocation in multi-echelon assembly systems with linked substitutes.” *Computers and Industrial Engineering*, 45, 43-60.

Choobineh, F. and E. Mohebbi. 2004. “Material planning for production kits under uncertainty.” *Production Planning & Control*, Vol. 15, No. 1, 63-70.

De Souza, M.C.; C.R.V. de Carvalho; and W.B. Brizon. 2008. “Packing items to feed assembly lines.” *European Journal of Operational Research*, 184, 480-489.

Ramachandran, S. and D. Delen. 2005. “Performance analysis of a kitting process in stochastic assembly systems.” *Computers & Operations Research*, 32, 449-463.

Som, P.; W.E. Wilhelm; and R.L. Disney. 1994. “Kitting process in a stochastic assembly system.” *Queueing Systems*, 17, 471-490.

BIOGRAPHY

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