18TH EUROPEAN CONCURRENT ENGINEERING CONFERENCE 2012

ECEC'2012

8TH FUTURE BUSINESS TECHNOLOGY CONFERENCE

FUBUTEC'2012

EDITED BY

Ciprian Dobre

and

Nicolae Vasiliu

APRIL 18-20, 2012

BUCHAREST, ROMANIA

A Publication of EUROSIS-ETI

Printed in Ghent, Belgium

18TH EUROPEAN CONCURRENT ENGINEERING CONFERENCE

8TH FUTURE BUSINESS TECHNOLOGY CONFERENCE

2012

BUCHAREST, ROMANIA

APRIL 18-20, 2012

Hosted by

JW Marriott Hotel

Organised by

ETI

University POLITEHNICA of Bucharest

Sponsored by

EUROSIS

LMS

BITE

University of Skovde

Higher Technological Institute
Tenth of Ramadan City

Ghent University

ECEC International Programme Committee

7.Formal Methods
Mauro Iacono, Seconda Universita di Napoli, Caserta, Italy
Yan Luo, NIST, Gaithersburg, USA
Stefano Marrone, Seconda Universita di Napoli, Caserta, Italy
Rachel Moreau, Hasselt University, Diepenbeek, Belgium

8.Collaborative CE environments for virtual teams
Khalil Drira, LAAS-CNRS, Université de Toulouse, Toulouse Cedex, France
Paul Stratil, Stuttgart, Germany
Roman V. Yampolskiy, University of Louisville, Louisville, USA

9.CE Enhanced Lean Manufacturing
Christian Hillbrand, V-Research GmbH, Dornbirn, Austria
Jean-Claude Hochon, AIRBUS, Blagnac, France .
Rik Van Landeghem, Ghent University, Zwijnaarde, Belgium .
Rob Walker, Anglia Ruskin University, Chelmsford, United Kingdom

10.Practical Applications and Experiences
Florin Pop, University POLITEHNICA Bucharest, Bucharest, Romania

11. Factory Planning and Control for Small and Medium sized Enterprises (SME's)
Sílvio do Carmo Silva, University of Minho, Portugal
Luís António Nunes Lourenço, University of Beira Interior, Portugal
Paulo J.S. Gonçalves, Polytechnic Institute of Castelo Branco, Portugal
Nuno O. Fernandes, Polytechnic Institute of Castelo Branco, Portugal
António M. Fernandes, Polytechnic Institute of Castelo Branco, Portugal
Veronique Limere, Ghent University, Ghent, Belgium

12. Digital Direct Manufacturing
Philippe Geril, ETI, Ostend, Belgium
Peter K. K. Loh, Nanyang Technological University, Singapore

13. Patient Centered Health Care with Meaningful Use of IT
Gurdev Singh, State University of New York at Buffalo, Buffalo NY, USA

14. Student Session
Prof Algirdas Pakstas, London Metropolitan University, London, UK

FUBUTEC International Programme Committee

Statistical Analysis and Data Mining of Business Processes

Paulo Alexandre Ribeiro Cortez, University of Minho, Guimaraes, Portugal
Danny Van Welden, KBC Bank, Brussels, Belgium

Discrete Event Simulation and Queueing Systems in Business and Economics

J. Manuel Feliz Teixeiro, FEUP-University of Porto, Porto, Portugal
Leonid Novickis, IDC Information Technologies, Riga, Latvia

Agents in Business Automation and Economics

Martin Fredriksson, Blekinge Institute of Technology, Karlskrona, Sweden
Markus Koch, Orga Systems GmbH, Paderborn, Germany
Isabel Praca, Polytechnic of Porto, Porto, Portugal

Simulation in Business and Economics

Thomas Hanne, University of Applied Sciences Northwestern Switzerland, Olten, Switzerland
Sudhir Mudur, Concordia University, Montreal, Canada
Yan Luo, NIST, Gaitherburg, USA
Simon See, Oracle Systems, Singapore

Simulation in Business Games

Renate Sitte, Griffith University, Gold Coast, Australia
David Wortley, Coventry University, Coventry, United Kingdom

Simulation in OR and Knowledge Management

Carmen Bobeanu, Ghent, Belgium
Chrissanthi Angeli, Technological Institute of Piraeus, Athens, Greece

Emergency Management and Risk Analysis Management

Kamil Drira, LAAS-CNRS, Université de Toulouse, Toulouse, France
Gurdev Singh, UB Patient Safety Research Center, State University of New York at Buffalo, Buffalo NY USA
Lode Vermeersch, KBC Goldstate FMC Co, Shanghai, China P.R.

Simulation in E-Management, E-Government, E-Commerce and E-Trade

Vrassidas Leopoulos, Nat. technical University of Athens, Athens, Greece

Simulation Tools for Business Management and Business Intelligence Simulation

Carlo Meloni, Politecnico di Bari, Bari, Italy

Measuring the Costs and Effects of Environmental Policies for Business

Dietmar Boenke, Hochschule Reutlingen, Reutlingen, Germany
Elias A. Hadzilias, Universite Catholique de Lille, Lille, France
Roberto Razzoli, University of Genova, Genova, Italy

Ecological sustainable development and Innovative technologies for a bio-based economy

Philippe Geril, ETI Bvba, Ostend, Belgium

ECEC
2012

FUBUTEC
2012

All articles published in these Proceedings have been peer reviewed

EUROSIS-ETI Publications are ISI-Thomson and IET referenced
Legal Repository: Koninklijke Bibliotheek van België, Keizerslaan 4, 1000 Brussels, Belgium
CIP 12.620 D/2011/12.620/1

For permission to publish a complete paper write EUROSIS, c/o Philippe Geril, ETI Executive Director, Greenbridge NV, Wetenschapspark 1, Plassendale 1, B-8400 Ostend Belgium

EUROSIS is a Division of ETI Bvba, The European Technology Institute, Torhoutsesteenweg 162, Box 4, B-8400 Ostend, Belgium

Printed in Belgium by Reproduct NV, Ghent, Belgium
Cover Design by Grafisch Bedrijf Lammaing, Ostend, Belgium

EUROSIS-ETI Publication

ISBN: 978-90-77381-70-0
EAN : 978-90-77381-70-0

Preface

It is our great pleasure to welcome you in Bucharest, Romania, for the European Concurrent Engineering Conference (ECEC 2012) and the FUture BUsiness TEChnology Conference (FUBUTEC 2012). As simulation, integrated knowledge management and concurrent technologies are regarded as the driving forces behind some of the world's largest and most successful business organizations, this year the conferences are proud to host together many specialist and expert in concurrent engineering, business technology, and computer science. The conference is held on April 18th-20th, 2012, and supported by the University POLITEHNICA of Bucharest, Romania and LMS.

The ECEC conference aims to identify the progress made in Concurrent Engineering over the previous twelve months. The ECEC conference has a long-lasting tradition in providing a dissemination forum for information and exploitation of results from the research and technical development and provides a forum for the exchange of experiences in developing and implementing CE based solutions across the wide spectrum of manufacturing and engineering industries.

The FUBUTEC conference is meant to integrate business technology research of present day business practices such as "Operations Research" or "Business Process Simulation" into an even higher level enterprise wide framework with its new work roles, responsibilities, reward systems methods and tools. In other words, attaining true knowledge management is about radical and fundamentally new ways to create retain share and leverage knowledge of people and organizations in ways that were simply not possible before. Next to the integral simulation part, the conference provides a strategic business overview of knowledge management in all its varied applications. In this aspect, the conference focus is on the latest knowledge strategies that business leaders need in order to become a Knowledge Organization and to withstand the forces of the financial and management markets in the present day precarious society, which constitutes the global environment.

Both these conference provide an open forum for researchers from academia and other research community to present, discusses, and exchange related ideas, results, and experiences in these areas. They aim at stimulating synergies between these new approaches, business technologies and knowledge management, risk analysis and intelligent data analysis, and the traditional models in this domain.

We would like to thank all the authors for submitting their research works within the conferences, as well as to the authors of accepted papers for their participation and presentation of the papers during these events.

We look forward to meet you all again in the 2012 edition of the conferences!

FUBUTEC General Conference Chair
Nicolae Vasiliu, University POLITEHNICA of Bucharest, Romania

FUBUTEC General Conference Chair
Ciprian Dobre, University POLITEHNICA of Bucharest, Romania

Secretary General EUROSIS
Philippe Geril, EUROSIS -ETI

CONTENTS

CONTENTS

KNOWLEDGE ENGINEERING

SCIENTIFIC PROGRAMME

COLLABORATIVE ENGINEERING

COLLABORATIVE PRODUCT DESIGN & DEVELOPMENT PROCESS MODELING

Bruno Raffaele Trinchera
Business Process Improvement
Via Bruxelles 2/B, 20097 San Donato Milanese
Milan, Italy
E-mail: Bruno.Trinchera@buprim.com

KEYWORDS
Process Modeling, Process value, Process Gates, Concurrent Engineering, Synergic Relationships, Complexity Analysis.

ABSTRACT

The modeling of effective product design and development process help manage the overall process efficiently and help organize a multifunctional team to develop products in a concurrent and collaborative manner. In this article, product design and development process is modeled as a value creation sequence rather than an activity sequence introducing the value creation events or gates.

THEORETICAL BACKGROUND

The methodological background to process modeling is approaching the product design and development process as a relationships sequence among organizational roles and tasks clustered by the product architecture tree.

"The relations between tasks, namely, complementarities or substitutabilities and synergies, determine the allocation of knowledge among members of the organization. Communication shapes the relation between individual, and governs the organizational process and structure that integrates disperse knowledge to perform tasks more efficiently" (Garicano and Yanhui 1983)

Relationships are identified and sequenced according to their specific aims and values generated along the product design and development.

'Values' of process modeling are referenced throughout this paper. Key values are identified as:

- The business need, required outcome(s) and time scales
- The process objects, objectives, requirements, variables and the value evidences
- The organization functional activities and accountabilities
- The individual and integrated competences.

The product design and development process is modeled as a value stream. Throughout, values are gathered from variables which structure progress towards the final process outputs.

'Added value' throughout the process is created by variables providing a significant contribution towards timely progress and delivery of the required outcome.

'Variables' are both tangible and intangible assets, for example raw materials or finished products and personal competences or customer satisfaction respectively.

The event that substantiates the values is represented by a control gate. Control gates are an intermediate or final inter-functional target i.e. the synergic connection point between sequences of activities executed by different functions.

This approach allows the design of suitable and faithfully process models helping to govern the intrinsic system complexity of the product design and development process.

NEW APPROACH TO BUSINESS PROCESS MODELING

Process modeling simplifies, structures and defines the design of a complete business process, for a broader definition of process modeling as part of process management discipline see Jeston and Nelis 2008.

This paper propose an innovative approach to business process modeling based upon two pillars

- Process Element Breakdown Structure
- Process Gate Map.

Process Element Breakdown Structure

Process element breakdown structure identifies and groups process elements with the objective of characterizing common targets, activities and accountabilities to the associated higher level level process.

According to the "Landscape theory" (Axelrod 1997), aggregation means the organization of elements of a system in patterns that tend to put highly compatible elements together and less compatible elements apart.

A Process Element represents a constituent key process and links multiple organization functions: e.g. linking Design Engineering, Manufacturing Engineering and Procurement.

Process elements are characterized by common attributes, namely:

- Targets & Deliverables
- Cross functional key characteristics
- Key Activities
- Key Accountabilities
- Sequencing
- Interaction between elements of a same process level.

Process elements are structured at different levels. For example, 'Transmission D&D' is a process element of 'Aircraft System D&D'; 'Gears D&D' is a process element of 'Transmission D&D'.

The definition and involvement of lower level process elements is restricted to company core competencies: 'in-house' design responsibility is a core competence as opposed to proprietary design of vendor parts, in such case the process modeling of vendor parts is limited to the uppermost system level element, for example Aerospace Engines, Windscreens and Bearings.

The next level of definition for a Process Element is identifying:

- Sequencing within each process
- Connections and dependencies
- Key accountabilities.

For clarification and communication purposes, an Accountability Matrix may be used to identify multiple Functions with accountabilities within the Process Element.

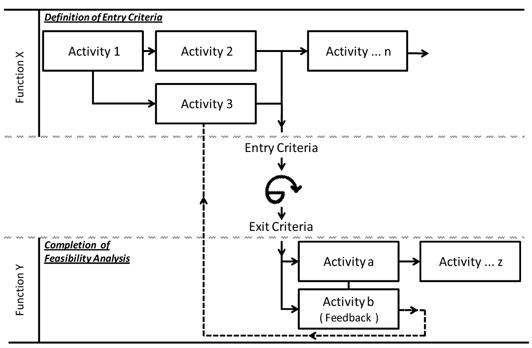
Process Gate Map

The output of Process Modeling is a Process Gate Map. A Process Gate Map positions control gates for each process element against a reference timeline (not necessarily representing elapse times) creating a process value chain by sequencing variables and activities assigned to multiple functions and specialists producing the required outcome.

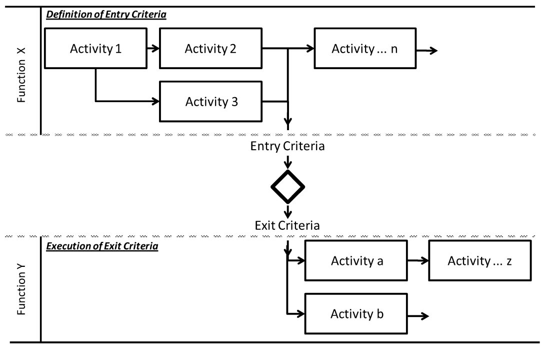
Process Gates
A Process Gate is a single event controlling a connection point among multi-functional activities, targeted at:

- Establishing common, shared and synchronized objectives within the business
- Creating a dedicated reference point for planning and control
- Scheduling a timely and disciplined feasibility analysis
- Representing a controlled exchange of information
- Enabling multi-functional decision-making by creating and communicate a defined closure status allowing the launch of subsequent activities at a known risk level
- Tracking concurrent activities.

There are two types of gates representing different control activities applicable to a Feasibility evaluation activity with a corresponding feedback loop and to an Execution activity



Figures 1: The Feasibility Gate



Figures 2: The Execution Gate

Gate Entry Criteria
Entry criteria is characterized in terms of 'level of confidence' in addition to 'level of completeness':

- The level of confidence is the minimal analysis and verification of data required to execute the exit criteria at an acceptable level of risk. Confidence in data is determined from current accuracy, uncertainty and stability of data as these attributes are required to manage the risk of subsequent change.
- The level of completeness is the minimum data required to execute exit criteria

Gate Exit Criteria
For both Execution and Feasibility gates, the identified exit criteria is the objective evidence demonstrating the commencement of the gate's activity in terms of value added to the process.

In principle for both types of gate, the status of exit criteria is categorized as either "Not Commenced" or "Commenced" determined by the progress of the Entry Criteria.

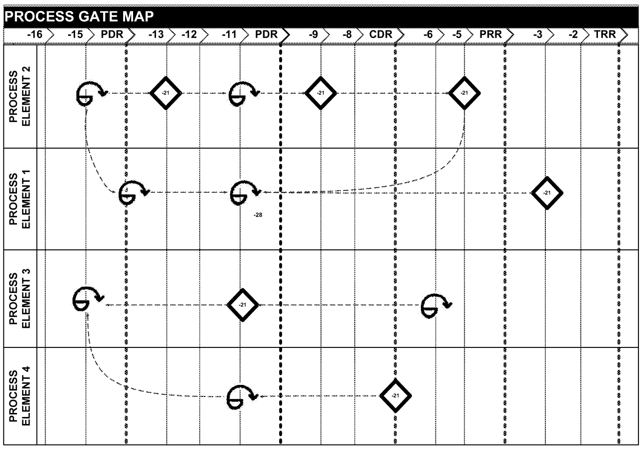
PROCESS GATE MAP: ADVANTAGES

Process Gate Maps clearly identify the sequencing of roles and accountabilities for each process element with the aim of:

- *Organize sequencing and concurrent deployment* such that activities only commence with a pre-determined minimum level of information
- *Determine an acceptable level of risk* defining the earliest connection point between activities
- *Identify the required information*, or variables, or interface parameters with an influence on downstream processes to enable the co-ordination of functions and activities in a timely manner (Zhang et al. 2006)
- *Identify the timing of Process gates* as a best practice trade-off considering the maturity of the minimum information required, the Process enablers required to commence activities and the Process enablers required for the timely completion of activities
- *Reduce operating and product costs, improve schedule performance and strengthen the Quality ethic* by focusing upon eliminating non value added activities, re-sequencing and regrouping design tasks to reduce complexity, increasing the efficiencies of value added activities, strengthening measures to assure Process adherence and standardize common methods of working

- *Continually take into account the 'human element'* of operating Processes: maximizing the utilization of available competencies, avoiding reducing efficiency and effectiveness due to information overloading and high stress levels, focusing upon assigning clearly defined objectives and accountabilities, removing functional barriers, reducing functional levels, using open communication and increasing business awareness.

Applicable key events may be placed on the TimeLine, e.g. PDR, CDR, PRR & TRR.



Figures 3: Example of a process gate map

PROCESS GATE MAP: THE TREASURE HUNT

Defining a process using the process gate concept means design the value process map as a process treasure map. The basic questions that a process map should answer are:

1. *Which are the treasures?* i.e. the identification of the added value along the process: the value inside the process is determined by the variables that contribute significantly to the final process result and that allow its progress. The variables are tangible assets (like raw materials, finished products …) or intangible assets (like information, value, competences, customer satisfaction …)
2. *Which is the way to gain the treasures*? With the treasures map, i.e. define the optimal activities sequence (effective - which activities are needed; efficient - when these activities should start) to valorize the variables, the distribution of the values: placing along a timeline the specific moments in which the variables are valorized
3. *Where I can find the values? …on the gate*
4. *How the treasures map is developed?* Coordinating the integration of all actors involved, i.e. the process represents the real activities sequence, it "captures" the best practice between all the possible realistic sequences with which activities are executed optimizing the contribution of the various actors inside the logical development activity sequence.

PROCESS GATE MAP: DESIGN GUIDELINES

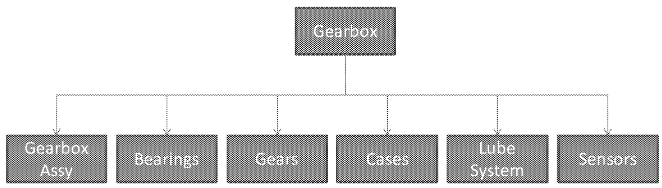
According to the above mentioned the following basic guidelines are applied for process gate mapping:

- *don't postpone tomorrow what you can do today;* Organize the sequence to start the activity as soon as the minimum required information are available
- *start when you are confident;* define the acceptable risk level to start as early as possible the activity
- *carpe diem;* identify the information (variables) that influence the forward processes in the time in which they are generated so that the early contribution coordination of the "forward" actor is feasible, to eliminate the needs of unplanned, with high implementation cost changes, identify the time in which the information is available and its change is feasible
- *sharpen the wits;* don't be damaged, contribute to the value creation the activities that can increase the value to avoid the rework, shorten the time and the costs. Eliminate the activities that do not bring to the treasure. Standardize and promote common methods. Increase the efficiency of the value added activities
- *the value of a company are people;* organize the work: maximize the use of the process actors' competences and available time. Avoid activity blocks and induced stress due to useless information overload. Focus on clear and shared objectives and without uncertainty on responsibilities. Start the activity at the right moment, avoiding too much in advance or late start.

PROCESS GATE MAP: AN EXAMPLE

As an application of the methodology we consider the detail design and first development of the aerospace Gearbox system, starting from the end of system definition (with the "transmission study") till the beginning of the drive system functional tests (see also Huang and Gu 2000).

The activities are grouped in elements at a first level according to the following breakdown.



Figures 4: Gearbox D&D process elements breakdown

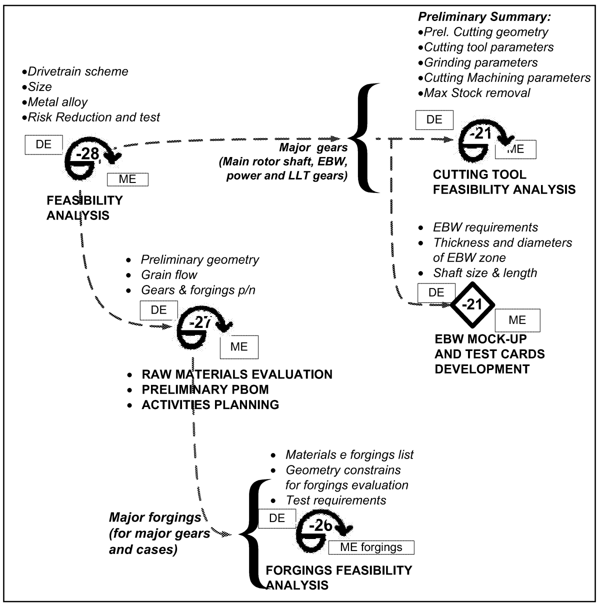
The process elements identified above are carried out concurrently, they constitutes the inter-functional base processes required to develop the gearbox system.

For example, the process element Gears contains all the activities carried out to develop the gears of the gearbox system, it is modeled according to the following criteria:

- the separation of the development activities of gear's teeth and gear's shaft
- the separation of the gears into two main group, major and minor gears, according to priority required for the detail design and development. Major gears includes, but is not limited to, main rotor shafts, Electron Beam Welded, power gears
- Execution of main rotor shaft fatigue test, requiring the development of specific rig's dummy and simulated parts and instrumentation
- Long lead time forgings development

- Interaction with bearings development process

The gearbox detail design and development process gate map represents the timeframe distribution for each process element; it shows time intervals, key events-reviews and process gates.



Figures 5: Gearbox D&D process gate map (extract)

PROCESS GATE MAP: DEPLOYMENT

Six Sigma defines quality as "the value added by a productive endeavor" and this quality may be expressed as potential quality and actual quality. Potential quality is the known maximum possible value added. Actual quality is the current value added. The difference between potential and actual quality is waste (Pyzek and Keller 2010).

Essential to effective Business Process Deployment is the requirement to adhere to the outputs of the preceding stage Process Modeling, to ensure:

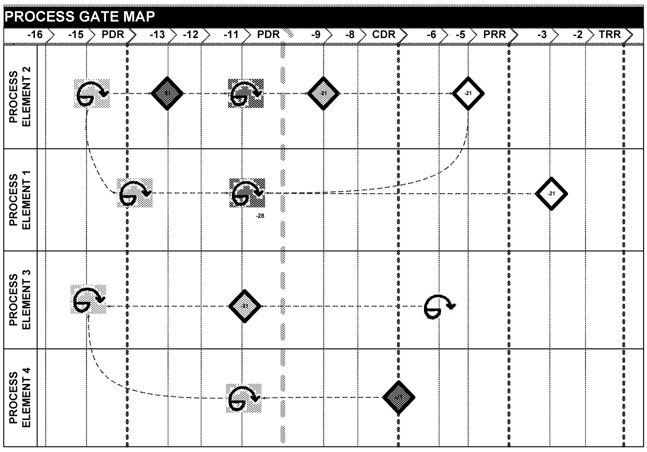
- The benefits of the process value chain are realized
- The timely delivery of the business demand is demonstrated and achieved
- The timely incorporation of change and stakeholder requirements are addressed
- Process modeling and the process gate map are used to drive process deployment
- Disciplined progress, performance measures and status reporting are achieved by adhering to the gate closure rules specified
- Continuous status reporting is summarized, collated and reported centrally
- The outputs from process deployment provides an input into existing program management and business control infrastructures
- Process deployment supports the dynamic principles of the process management system by collating and providing feedback of strengths & weaknesses as inputs to process appraisal and improvement.

Process Status Monitoring

Subject to the rules specified in this document, disciplined gate closure is established:

- execution and tracking of Entry & Exit criteria for each gate via the Execution Book
- KPI measurement compliance to the process gate map for each process element
- The structured of objective evidence and gate closure status
- Reporting and controlling emergent risks.

The current status of gate closure shall be communicated using 'traffic lights' Red – Amber – Green to represent one of three status conditions on the process gate map.



Figures 6: The Red, Amber, Green Closure Gete Status

The status represents the level of risk against the specified requirements of each gate. This status takes into account the impact of gate completion relative to the current date, i.e. the combination of gate status and position relative to the current, past or future months.

- For each month the closure status is evaluated
- The status is evaluated from the worst to best case represented as Red, Amber or Green
- For previous months the evaluation is based upon the status of exit criteria and therefore the completion of entry criteria
- For future months, the evaluation is based upon the capability to reach the target entry criteria
- The 'look ahead' shall be over a minimum period of 3 months.

Therefore, the status is converted to Red, Amber or Green for two timeframes: current & previous months and for future months. This is summarized as follows:

Table 1: Process Gates Status

COLOUR STATUS	Current & Previous Months		Future Months
	Feasibility Gate *Exit C. = Analysis*	*Execution Gate* *Exit C. = Activity*	*For both Gates types Definition of Entry C.*
RED	NOT COMMENCED	BLOCKED	LOW
AMBER	IN PROGRESS	NOT COMMENCED	MEDIUM
GREEN	COMPLETED	COMMENCED	HIGH

Gate Closure Rules

Rules are specified for gate closure to invoke consistent, effective valuation of gate status and communicate any impact on timely completion.

Gate status is determined by the process owner from the completion of entry and exit criterion. Both criteria are measured to prevent downstream delays and additional costs incurred from uninformed decisions to progress onwards at an unknown level of risk.
Gate closure rules are based upon:

- The level of confidence is viewed as equally important to the level of Completeness
- Confidence (Cf), is determined from objective evidence supporting the level of acceptable risk and uncertainty
- Completeness (Cp), is determined from objective evidence supporting 100% completion
- Exit criteria for both types of gates is measured by a status of 'Not Commenced' or 'Commenced'

Status Reporting via the Electronic Execution Book
The Electronic Execution Book, EEB, shall be used by the process owner to execute the process gate map to determine, record and communicate the current status of each Gate.

The Electronic Execution Book shall:

- Consist of one 'page' of data per Gate
- Be populated with the specified Entry & Exit criterion to determine the status of each gate
- Be electronically created, maintained and communicated
- Incur low administration effort
- Calculate and record for each gate the red, amber, or green status for the current month, for all previous months and for 3 month (minimum) look ahead
- Provide an auditable link to corresponding progress methods, objective evidence and actions
- Be date controlled and provide an historical record of previous status reports.

CONCLUDING REMARKS

This paper presents a few hints on how to approach complex process modeling in concurrent environment, capturing and sequencing essential organizational relationships, relevant aims, critical variables and values.

The process gate map approach has been developed to analyze organizational knowledge, process and structure of the concurrent product design and development process, enabling creating an effective business management system linking and integrating interrelated disciplines:

- *Collaboration Relationships;* studying competition and collaboration behaviors applying the so called complexity theory to study gates involving many actors and their interactions, through research tools such as simulation of agents and their interaction, known as agent-based modeling and use them to design more effective processes and organizations (Axelrod 1997) (Sterman 2000)
- *Process Improvement;* approaching the process management and all the related techniques i.e. process improvement, process re-engineering, statistical process control and lean (Jeston and Nelis 2008).
- *Design Structure Matrix;* integrating the Design Structure Matrix modeling approach to study the iterations and feedback loops in a new product design process to better plan and manage iteration, overlapping, decomposition and convergence problems typical of the feasibility gates of a concurrent engineering initiatives (Yassine and Braha 2006) (Eppinger et al. 1994) (Huang and Gu 2000) (Zhang et al. 2006).
- *Project Planning and Risk Management;* the process gate map is the base structure constituent or the "archetype" helping to design an effective project plan of concurrent product design and development. All work has structure, every process as realized has a structure and inherent risk, structure constrains a process in many ways, wrong structures limit and restrain, successful businesses need competitive structures, through process gate map we transform structure into a project plan used to control team tasks (Denker et al. 1999).
- *Knowledge Management;* capturing, organizing and sharing business knowledge, linking parameters relationship and rationale of design & development decisions to relevant gate, allows effective knowledge management: i.e. the reasoning behind decisions becomes available, participants affected by design changes can be identified, existing similar designs can be modified to meet current needs, the causes resolutions for conflicts can be identified (Klein 1993) (Zhang et al. 2006).
- *System Engineering and Configuration Management;* capturing and structuring requirements as specific entry criteria for relevant process gates allows product and performance configuration tracking along the concurrent product design and development.

REFERENCES

Axelrod R. 1997 "The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration," Princeton Univ., Princeton, NJ.

Denker S.; D. Steward, and T. Browning. 1999 "Planning Concurrency and Managing Iteration in Projects," Center for Quality of Management (CQM) Journal, 8(2): 55-62.

Eppinger S.D.; D.E. Whitney; R.P. Smith, and D.A. Gebala 1994 "A Model-Based Method for Organizing Tasks in Product Development" Research in Engineering Design, 6: 1-13.

Garicano L. and W. Yanhui. 2010 "A Task-Based Approach to Organization:Knowledge, Communication and Structure," CEP Discussion Paper No 1013.

Huang H.Z. and Y.K. Gu. 2000 "Modeling the Product Development Process as a Dynamic System with Feedback," Concurrent Eng.; 14; 283.

Jeston J. and J. Nelis. 2008 "Business Process Management: Pratical Guidelines to Successful Implementations". 2 ed., Elsevier.

Klein M. 1993 "Capturing Design Rationale in Concurrent Engineering Teams" Boeing Computer Services, IEEE Computer Journal. Special Issue on Computer Support for Concurrent Engineering.

Pyzek T. and P. Keller, 2010 "The Six Sigma Handbook"– Third Edition, 4.

Sterman J. D. 2000 "Business Dynamics: Systems Thinking and Modeling for a Complex World," Irwin Profess., McGraw–Hill, New York.

Yassine A. and D. Braha. 2006 "Complex Concurrent Engineering and the Design Structure Matrix Method," Concurrent Eng., 11: 165–176.

Zhang H.; W. Qiu and H. Zhang. 2006 "An Approach to Measuring Coupled Tasks Strength and Sequencing of Coupled Tasks in New Product Development," Concurrent Engineering; 14; 305.

A SEMANTIC ADAPTIVE FRAMEWORK FOR COLLABORATIVE SYSTEMS

Aymen Kamoun[1,2,3]
Saïd Tazi[1,3]
Khalil Drira[1,2]
[1] CNRS, LAAS, 7 avenue du colonel Roche, F-31400 Toulouse, France
[2] Univ de Toulouse, LAAS, F-31400 Toulouse, France
[3] Univ de Toulouse, UT1 capitole, LAAS, F-31000 Toulouse, France
E-mail: {akamoun|tazi|khalil}@laas.fr

KEYWORDS
Collaboration, semantic adaptation, dynamic reconfiguration.

ABSTRACT

The collaboration environments are context sensitive; they may be subject of modification whenever parameters of use change. Dynamic adaptation is a key issue to enable continuity of collaboration and communication.
In this context, the collaborative development of products provides new challenges in distributed systems. It requires continuous communication and exchanges between teams of collaborators having different roles and using different tools. A global model of collaboration is necessary to guarantee the quality of communication and to ensure adaptability and interoperability between tools whatever may happen. In this paper, we present a framework for collaborative model-based services development that supports a semantic adaptation model. This framework enables a dynamic deployment of component that is triggered by the change of collaboration context such as the arrival/absence or change of roles and tasks of actors. In this article, the implementation of the framework and its conceptual model are presented. A test case for collaborative software development has been developed to validate the framework.

INTRODUCTION

The collaborative development of complex products provides a wide range of new challenges in distributed systems. Teams of engineers have different roles and experiences; they must deal with numerous types of information both on the product being developed, on the technology used such as the development tool, but also on the organization adopted for work. It is important to guarantee transparent collaboration of actors respecting the different roles they are playing and despite the distance and the disparate tools they are using for collaboration and communication.

The design of collaborative systems that deliver intelligently the communication flows between the different parts in all situations ensuring the continuum of collaboration is one of CSCW (Computer-Supported Collaborative Work) research challenge (Carstensen and Schmidt 1999). For example if a collaborator joins/leaves or changes his role within a project, how the system may enable/disable automatically the communication flow adapted to its context of use such as its role, optimized Quality Of Service parameters? How his collaborators may continue their work despite this change? And how the system may ensure the continuum of collaboration by providing new flow of communication regarding the role of each collaborator and their tasks? In this perspective, we propose to explore promising research methodology grounding on analysis of semantic collaboration to ensure interoperability and thus the communication. A global model of collaboration is necessary to guarantee the quality of communication and to ensure adaptability whatever may happen of such events.

In this paper, we focus on architectural adaptation in collaborative environments in which actors have different roles and belong to one or many groups. Therefore, they are organized within sessions dynamically depending on their roles or tasks. In order to achieve this adaptation, a set of interconnected components must be deployed in the system. Since sessions are dynamic and actors may change their roles during the collaborative activities, an adaptive components deployment must be considered in such systems to preserve this collaboration.

This paper deals with semantics of collaboration. An analysis of related work is presented. A multi-level modeling approach and a framework for adaptive group communication are also presented. Based on this framework and on a conceptual model of collaboration, an architecture enabling the adaptation of the collaborative engineering systems is proposed with a test case in the domain of collaborative software development.

STATE OF THE ART

Significant research has been carried out on collaborative activities and session management. A majority of these solutions deal with different aspects of collaboration and communication. However, as far as we know, very few works treat specifically the problem of providing tools for building context-aware collaborative applications with dynamic reconfiguration of components at runtime.

According to Dourish and Bellotti (Dourish and Bellotti 1992), “Awareness of individual and group activities is critical to successful collaboration and is commonly supported in CSCW systems”. In CSCW, the notion of group awareness presents a significant feature. Dourish and Bellotti (Dourish and Bellotti 1992) defined it as "an understanding of the activities of others, which provides a context of your own activity”. This concept depends on the group topology such as members who have strong or weak relationships or members

who have different or same experiences (Palmer et al. 1994). Moreover, as members are not co-present in virtual workspace, it is prominent to create a group awareness model based on different methods such as providing a clear synthesis of all information from different parts of system.
Communication presents a fundamental feature in collaborative workspace. During team meetings, the members share documents and they can explain directly what they mean. But, communication problem becomes more complex when participants are distant collaborating in an asynchronous mode. As a result, communication matters can have a direct drawback on the shared knowledge. This can have thereafter an impact on project progress. Many studies have so addressed mediated communication issues between designers (Lewkowicz et al. 2008), (Edwards 2005).

Baudin et al. (Baudin et al. 2004) has thoroughly studied graph-based explicit session management models and services in order to support collaboration inside groups of human users. The goal was to explicitly model relationships of information exchange between users in order to keep a tight coupling between communication and network layers. The proposed graph-based collaboration model is based on data producer/consumer relationships. Therefore, data exchanges for synchronous and interactive work sessions are represented and modeled. Such sessions handle interactive data flows (e.g. video, real time audio). The dynamics of the session is expressed in terms of users entries/exists and user role changes. The session designer explicitly selects collaboration graph structures where collaborative work can occur. Advantages of this collaboration model are twofold. Firstly, this model is simple enough to be easily handled by session designers for various collaborative configurations. Secondly, instances of this model can be automatically taken into account by services or platforms that can be configured by the model. The sessions explicitly designed are therefore managed by model-based platforms.

Implicit sessions emerge from the observation of users' actions and their context. When the system detects a potential situation of collaboration, such as human presences, it creates an implicit session and invites involved users to join it. As far as we know, few works were tackling implicit sessions. However, we can cite (Edwards 1994) and (Texier and Plouzeau 2003) where models are based on set formalisms or (Rusinkiewicz et al. 1995) where models are based on first-order logic formalism, in order to describe unstructured sessions.

We have analyzed existing synchronous collaborative systems such as TANGO (Beca et al. 1997), HABANERO (Chanbert et al. 1998), DOE200 (DOE200 1999) and DISCIPLE (Marsic 2000). The main disadvantage of these systems is that the group member roles are pre-defined and cannot be changed dynamically during the collaborative activities. Consequently, these systems cannot support complex structured sessions. Thus, model-based approaches are required in order to describe session's organization and to ensure the flexibility in the described systems. Moreover, several approaches propose models controlling only one element of the session such as media (Holvoet and Berbers 2001) and collaborative services (Vissers et al. 2004). Other sessions models describe only three components of a session: users, tools and data flows (Edwards 1994) [Dommel and Garcia-Luna-Aceves 1999). These proposed models create collaborative sessions by monitoring members' activities. Some of them support dynamic change and provide a representation of the sessions but this representation is too specific to the model, what restricts its use in other systems.

Some platforms provide tool-based implementation for the session management, whereas, they don't support the representation of complex structured sessions, and even those which allow complex sessions modeling are still theoretical and they don't provide real implementations.
Other awareness tools have been proposed: The TeamScope system (Jang et al. 2000) allows participants exchanging files and working on it without real time interaction between them. The Classroom BRIDGE (Ganoe et al. 2003) and the Collablogger tool (Morse and Steves 2000) support distributed group projects. However, they are not able to support dynamic changes of the session's structure.

Other ontologies-based works are proposed and applied to different problems of CSCW. Yao et al. [Yao et al. 2007] introduce an ontology-based system for workflow management. This system can interact with other ontology-based applications. Andonoff et al. (Andonoff et al. 2007) proposes an ontology of high level protocols for agents conversations. Ontologies are used in order to provide semantic to these protocols and to ensure automation of coordination in distributed systems. Garrido et al. (Garrido et al. 2007) propose an MDA-based approach for modeling enterprise organization and developing groupware applications. The domain model is formalized through a domain ontology in order to describe concepts and relations between actors sharing knowledge. Tomingas and Luts propose a semantic interoperability framework for data management like web services descriptions and ontologies (Tomingas and Luts 2010).

The main disadvantage of classical CSCW systems is the lack of flexibility in sessions which are pre-defined and don't support dynamic changes. Indeed, a given CSCW system, which supports collaborative activities in a specific domain and in particular in a specific group organization, cannot coordinate collaborative activities in another domain; and even in a particular working group, sessions and roles organization cannot be changed. Few works consider implicit sessions which are spontaneous and depends on implicit collaboration activities. In systems represented above, sessions are initiated explicitly and the dynamic of changes is limited to roles changes. Moreover, if a new situation of collaboration is required at runtime, the system is not able to provide the adequate service which satisfies users' needs. Thus, session designer should define new sessions' structure. Furthermore, even if a system defines all possible sessions, it should be implemented and hard-coded. This method limits the code reutilization and its maintenance. Therefore, a generic framework that defines common vocabulary for session modeling is needed. Session designers should easily define and implement new session structures for different

groups working together and even for the same group at runtime.
Another disadvantage of these systems is the lack of rigid deployment services of components or application that they offer. Components and applications are often deployed manually on participants' machines and fixed at design time by a static way. This method cannot be applied to situations that need a high degree of adaptation, and in which even not known components should be deployed in advance.

In our work, we intend to support collaboration in distributed environments where sessions can be implicit, new mechanisms are needed for managing session evolution and role changes. In our view, Semantic Web techniques are well suited to achieve this task. As far as we know, there is no existing collaborative system that use semantic for session management and dynamic deployment service. As thus, in this paper, a semantic driven framework has been developed to enable session management and dynamic components deployment for collaborative systems. The next section will describe our approach towards the framework we have developed.

PROPOSED SOLUTION

We present our proposed solution for the modeling and the implementation of collaborative activities. We propose a generic framework enabling session management, semantic multi-level adaptation and automatic components deployment for collaborative activities.
This framework is based on a generic multi-level modeling approach (Figure 1) that ensures multi-level adaptation. Each level encapsulates specific problems into a specific model. Models represent sets of linked entities like software components, called configurations. High level configurations represent high level requirements, such as participants' organization and their activities, while low levels configuration represent the real implementation ensuring such activities. Separation between levels may introduce the concept of multi-level adaptation. Indeed, distinguishing different abstraction levels allows mastering the specification and the implementation of adaptation rules.

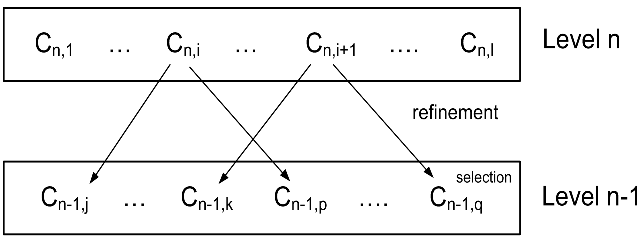


Figure 1: Multi-level architecture modeling

A configuration is denoted $C_{n,i}$, where n is the abstract level and i is an index to distinguish the configuration. For a given configuration $C_{n,i}$ at level n, multiple configurations ($C_{n-1,1}$,…,$C_{n-1,p}$) may be implemented at level n-1.These configurations represent the refinement or a detailed view of $C_{n,i}$. When a new adaptation is required at level n, only one configuration is chosen among all configurations of this level implementing the n-level configuration.

Framework architecture

In this part, we present how we apply the presented multi-level approach to collaborative systems in order to clearly identify specific problems of each level for the considered system. Therefore, we provide an overview of the retained level and we detail the proposed models for each level. Adaptation at the highest levels should be guided by the evolution of activity requirements. Adaptation at the lowest levels should be driven by execution context constraint changes. The framework architecture and the retained levels are represented in Figure 2. These levels are detailed as follows:

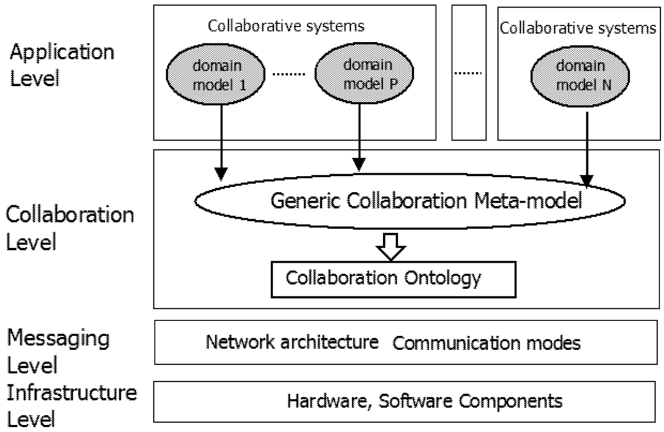


Figure 2: Framework architecture

Collaboration Level
The goal of the central level (collaboration Level) is to provide collaboration schema that enables members belonging to several groups to communicate inside sessions where they can send and receive data flows. Thus, the main issue in this level is to determine which data flows have to be created in order to enable the needed communication. The proposed elements in this level are represented by a generic collaboration meta-model (GCM) which details the structure of one or more collaborative sessions and deployment configuration. Hence, new instances of this meta-model are generated at runtime after every context change of the application level configuration as well as arrivals, changing roles, changing groups of collaborating actors. GCM is a graph expressed in the GraphML language (an XML dialect for representing graphs (Brandes et al. 2001)).

In order to represent GCM, we have chosen ontologies because it constitutes a standard knowledge representation system, allowing reasoning and inference. Moreover, ontologies facilitate knowledge reuse and sharing through formal and real world semantics. Therefore, ontologies are high-level representations of business concepts and relations. We have chosen to describe levels' models in OWL (Smith et al. 2004), the Semantic Web standard for metadata and ontologies. In general, ontologies are separated in two levels: a generic ontology and a specific ontology. The former is a domain-wide ontology, but independent of applications. The latter ontology extends the generic one with terms specific to

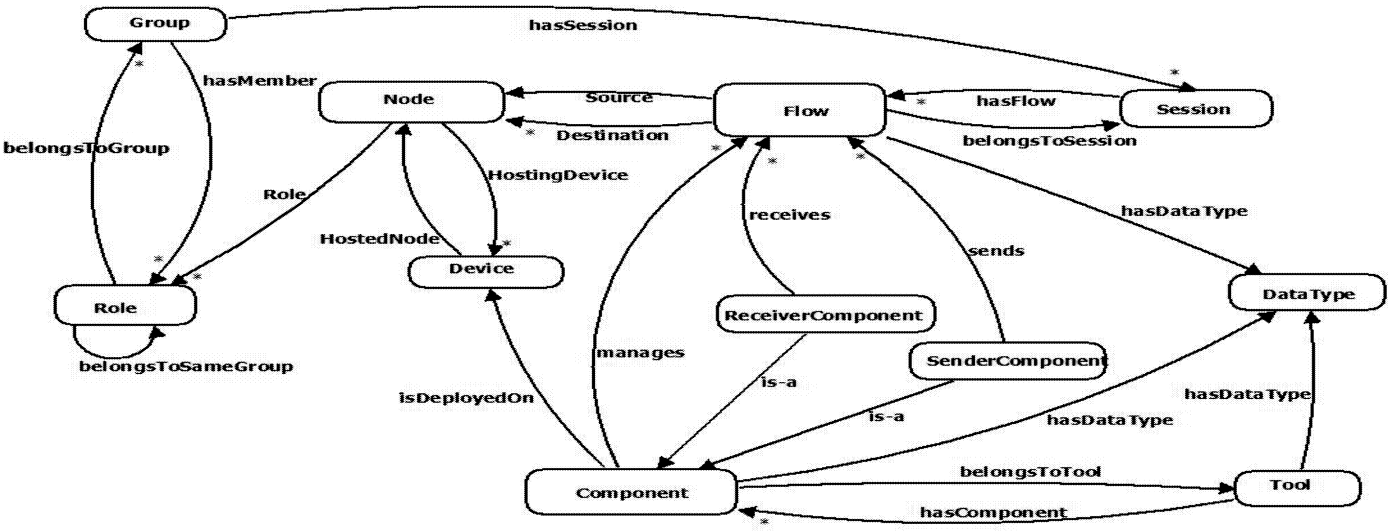


Figure 3: Generic collaboration Meta-model

an application category. We have followed the same pattern in our implementation: there is a generic ontology, GCM, and an application ontology that extends the collaboration ontology with business-specific concepts and relations.
The generic ontology is common to all applications, therefore it is provided within the framework. The main elements of this ontology which represents our Generic Collaboration Meta-model are detailed in Figure 3. The proposed concepts are represented by round-cornered rectangles, while relations are represented as arrows going from one concept (the domain) to another (the range).

The main concept is *Session*. A session is a set of flows, represented by the concept *Flow*, which represents communication links between entities. A property, called *HasdataType*, relates the concept *Flow* to the *DataType* concept. Possible values of data type are captured by the *DataType* instances that can be text, audio, video or an exchanged artifact between actors. During the collaborative activities, flows are exchanged between communicating entities represented by the *Node* concept. Therefore, *Flow* is related to *Node* by the two relations: *source* and *destination* representing respectively the source node and destination node. Nodes may represent actors. A given node plays one or more roles determining the type of each activity for all involved actors. For example, a role may be a developer in a collaborative software engineering. Depending on their roles, entities will have multiple tasks and they need to communicate with different members organized within different groups in order to achieve collaboration goal.
Each role belongs to one or several groups. Therefore, the concept *Role* is related to the concept *Group* by the relation *belongsToGroup*. In order to manage collaboration sessions, a set of session must be defined for each group. Therefore the relation *hasSession* relates the *Group* concept to the *Session* concept. The session definition for each group enables a valid deployment of appropriate sessions depending on participants' roles and groups.
Whether a node represents a collaborative entity that communicates with others entities, it has to be hosted by a physical machine represented by the *Device* concept (relation *HostingDevice*).

Nodes manage exchanged data flow using external components (*Tool* concept) deployed on the same devices in order to enable the separation between collaboration code (implemented in the external components) and the business code (implemented in entities' components and specific to the application). Tools are composed of one or several components (e.g. a sender component and a receiver component) represented by the concept *Component*. The *Tool* concept is related to the *Component* concept through the relation *hasComponent*. Components manage several flows. Therefore, the relation *manages* relates *Component* to *Flow*. Components have the same data type of the managed flows (relation *hasDataType*). Each component is deployed on one device (relation *isDeployedOn* which links *Component* and *Device*). The component' type depends on the handled data type (text, audio, video, files, artifacts …) and on the communication mode (real-time communication, asynchronous communication).

Application Level
The retained model in this level is a domain specific ontology that represents concepts and relations modeling the context of the application. Such ontology depends on the application domain, hence it will be provided by the designer of the collaborative system using the framework. In general, this ontology is a specialization of the Generic Collaboration Meta-model presented above in order to enable the addition of specific semantics to the general collaboration concepts. Moreover, this ontology can be more complex depending on the application' needs.

The domain ontology contains also some rules indicating how roles can communicate, within the specified sessions.
At runtime, the domain ontology is instantiated depending on the application context, thus providing knowledge base containing explicit and implicit collaboration aspects about participants, their roles, their group and about the needed sessions for each group.

Messaging Level
The architectural model produced in this level is a detailed deployment schema that contains the needed elements in order

to implement collaboration sessions determined by the collaboration level. For this level, we have retained two communication paradigms: the Event Based Communication and the Peer-To-Peer communication. The EBC is based on the Publish/Subscribe pattern and it represents a well-established paradigm for interconnecting loosely coupled components and it provides a one-to-many or a many-to-many communication pattern. The main advantage of the EBC is the opportunity for better scalability than traditional client-server pattern through message caching and network-based routing. Moreover, publishers are loosely coupled to subscribers and they operate independently of each other. The Peer-To-Peer model allows to make some resources available in the network participants without a central coordination. Its structure is privileged for file sharing that represents an important activity in collaborative systems.

The produced models in this level are EBC-based graphs and Peer-To-Peer-based graphs that contain the specific needed elements for each paradigm. The EBC model contains a set of *event producers*, *event consumers* and *channel managers (CM)* connected with push and pull links. For every determined session, a CM is created in order to manage, store and deliver exchanged data flow between multiple producers and consumers. On the other hand, the Peer-To-Peer model contains peers, super-peer and pipes that enable the communication and the file sharing between actors.
These produced models are represented by graphs expressed in the GraphML language.
Since the produced model represents a detailed deployment descriptor, we provide a deployment service that effectively deploys elements on participants' devices. This deployment service takes a deployment descriptor as input in order to install, start and update the required components.

The implementation of this deployment service is based on the *Open Services Gateway Initiative* (OSGi) technology. Indeed, OSGi offers very promising functionalities such as dynamic code loading and execution. Besides, this specification offers a services management platform (with a dynamic register of services enabling the detection, the invocation, the addition, the cancellation of services at runtime). OSGI offers as well a complete and dynamic component model. In OSGI specification, components are called *bundles*.
Within this approach, deployable components are packaged as OSGi bundles that are handled by the proposed deployment service.

Refinement And Selection

The adaptation requires two actions: Refinement which determines the set of associated (n-1)-level configurations that implement a given n-level configuration; and Selection, which consists in retaining the optimal configuration among the all possible configurations at a given level.

Application–Collaboration Refinement
Reasoning based on SWRL rules (Horrocks et al. 2004) is used in order to implement the application-collaboration refinement. SWRL rules are applied to an instance of the domain ontology that extends the GCM. The proposed Generic Collaboration Meta-model includes 6 generic rules that express some relations and especially those which allow to infer a collaboration schema from the domain ontology instance. However, these rules are not sufficient for complete implementation of the refinement from the domain ontology to the collaboration ontology. Therefore the application designer has to specify additional rules in the domain application model which contains a part of the refinement process. The processing of the SWRL rules produces an instance of the Generic Collaboration ontology represented by a collaboration graph expressed in the OWL language. The application-collaboration refinement produces a single collaboration model from a given application level model.

Collaboration-Messaging Refinement And Selection
As the collaboration level and the messaging level models are represented by graphs, graph grammar theories represent an appropriate formalism to handle the refinement process. Moreover, graph grammar is an intuitive and powerful way of handling complex transformations.
In this graph grammar, non-terminal nodes are collaboration entities while terminals nodes are deployment entities. This refinement infers two sets of deployment graph: a set containing all possible EBC-based graphs where terminal nodes are EBC entities and another set containing all possible Peer-To-Peer-based graphs where terminal nodes are Peer-To-Peer entities.
In order to apply transformation's rules of the proposed grammar, a Graph Matching and Transformation Engine (GMTE) (Rodriguez et al. 2010) is used.

In order to select the optimal architecture among those built by the refinement process, a generic selection procedure is used depending on several parameters. This function allows: (1) to discard configuration that cannot be deployed, (2) to select the best adapted configuration to the current context.

In order to ensure the framework robustness, we have retained two policies; however we can add new policies depending on the system requirements. The first policy, called *MaxDispersion*, maximize the dispersion of components deployed on participants' devices. The second policy, called *MinDistance*, minimizes and discards useless redeployments.

ADAPTATION IN COLLABORATIVE ENGINEERING

We explain how to take advantage of the proposed framework in order to maintain the collaboration between actors within enterprise systems in the advent of their dynamic. We provide methods that enable the dynamic adaptation of such systems and the optimization of the product development process by managing the collaborative sessions during all development phases of a given product. We also address the discovery capabilities in order to enable the detection of new changes on the situations of collaboration within the systems' network. These changes trigger a notification to our framework which launches the adaptation process using the proposed knowledge representation technologies applied to a given domain model. The result of this adaptation is a messaging model that decides in what way should the network nodes

react in order to enable the system to evolve for the new interoperable state.
In order to carry out the adaptation process during the collaborative engineering, three phases are required (Figure 4):

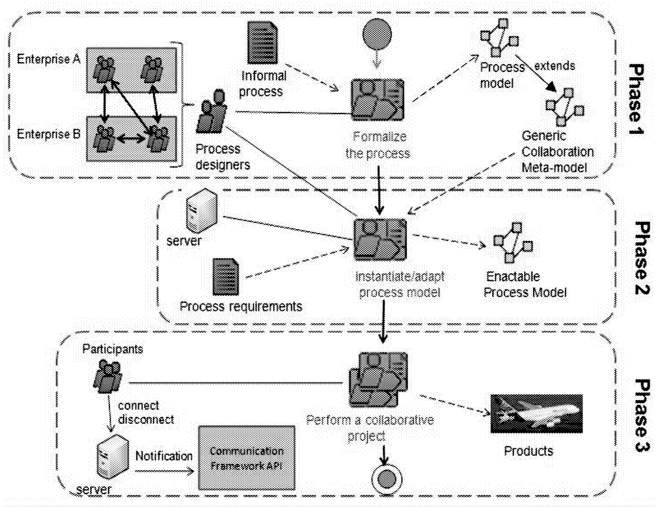


Figure 4: The three phases of adaptation

Phase 1

The process designers begin with defining a process model which contains specific concepts such as groups, roles, activities, relationship, constraints, automatic collaborative sessions for each group, etc. Application-specific SWRL rules are also defined and will be used by the adaptation process in order to determine to what session should belong each actor having a given role or task. This process model is a specialization of the Generic Collaboration Meta-model detailed above. During this phase, the process designers formalize the process depending on the needed structure that enable inter and intra-enterprise collaboration. For example, they formalize the collaboration between actors having a common experience, performing common tasks and belonging to one or more projects.
The main advantage of this architecture is that the process model can be updated at runtime without performing actions on the system's code implementation. This update may affect sessions' organization, groups' definition, possible roles, etc. For example, the process designers can add or remove one or more collaborative session of a given groups. Therefore, during the adaptation process, the system's server has a permanent HTTP access to the defined process model which can be updated.

Phase 2

Once the process model is detected, the system's server instantiates it and allocates to the project all resources (project plan). This instance represents the initialization of the application descriptor that will be the entry of the adaptation process. This phase produces an enactable process model that contains the defined specific concepts and relations defined in the process model such as all potential roles that may be played by actors, all possible groups that may represents sub-projects and mainly the defined collaboration sessions for all groups.

Phase 3

Once the process model is defined by the process designers and initialized by the system's server, actors will be assisted in performing the collaborative project according to the enactable process model, to their roles, to the teams' organization and to the defined collaboration scenarii.
Therefore, the system's server should enable the needed adaptation after each actions (such as change involving connection, disconnection , changing roles, joining or leaving a given working group) performed by each actor. Hence, the process model which has been instantiated and initialized in the phase 2 must be updated in order to represent all the performed actions. In the framework, this model represents the application descriptor which is the entry of each adaptation process.
In order to create dynamically the required application descriptors that represent the current collaboration state, a communication API is proposed enabling the interfacing with the proposed framework.

Once the application descriptor is created, the framework carry into effect the adaptation process. Firstly, a collaboration schema that responds to the high level needs is generated by the collaboration level through reasoning using SWRL rules defined both by the Generic Collaboration Meta-model and the process model. After that, the Graph Matching and Transformation Engine (GMTE) infers a set messaging graph representing all possible communication models. Then, the communication framework selects the well adapted messaging graph that ensures the needed communication between actors performing the collaborative activities. Finally, the deployment service takes charge of the effective deployment of the needed components.

TEST CASE

We consider a software engineering project concerned with the development of complex software products. The ultimate goal is to ease the development of such products by assisting engineers, whose are organized within different teams, in their collaborative work. The present test case is implemented in the context of the ANR Galaxy project (see http://www.irit.fr/GALAXY).
We detail the three required phases:

1. Phase1: In this phase, the process designer of the Galaxy project defines the process model which contains the groups, the possible roles and collaboration sessions for each team. Figure 5 describes a proposed domain ontology (expressed by an OWL file) that represents the collaboration aspect of the defined process model. In this figure, concepts and relations of the Generic Collaboration Meta-model are represented with continuous lines, while specific concepts and relations are represented in broken lines. The *Node* concept is specialized into the *Actor* concept which models a galaxy actor. For each actor, a set of possible roles, which specialize

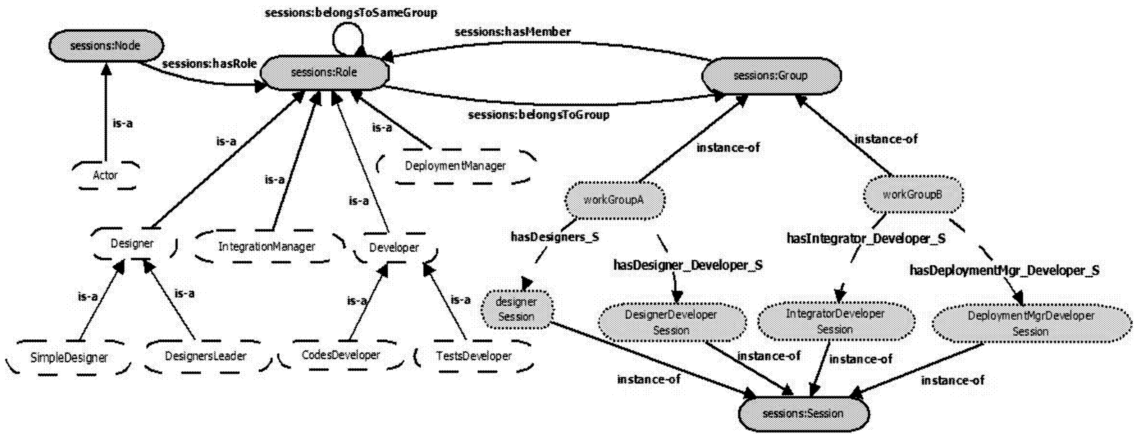


Figure 5: The proposed domain ontology

the *Role* concept, are defined:

- Designer: a designer can be:
  - Simple designer: designs and writes architecture description models.
  - Designers' leader: collaborates with the simple designers in order to produce the detailed architecture of the system.
- Integration manager: decides when features and fixes are ready for production, and merges them while being sure that the result is functional and reasonably bug-free.
- Developer: a developer can be:
  - Code developer: writes codes.
  - Test developer: writes integration tests for the system under development.
- Deployment manager: deploys the project to production, monitors execution, and reports errors back to developers.

Having one or more roles, engineers can belong to one or more working groups. The defined working groups for this project, *workGroupA* and *workGroupB*, are two instances of the *Group* concept of GCM (all instances are represented with dashed lines). For each working group are defined the associated collaboration sessions. Engineers who belong to the *workGroupA* are organized within two sessions: *DesignerSession* which regroups all project designers and *DesignerDeveloperSession* which regroups designers and developers. On the other hand, engineers who belong to the *workGroupB* are organized within the two sessions: *integratorDeveloperSession* which regroups the integration manager and developers when integrating the developed codes and *DeploymentMgrDeveloperSession* which regroups the deployment manager and the developers when a bug is found. These collaboration sessions are instances of the *Session* concept of the GCM. In order to assign sessions to the groups, the *hasSession* relation of GCM is specialized into four relations: *hasDesigner_S*, *hasDesigner_Developer_S*, *hasIntegrator_Developer_S* and *hasDeploymentMgr_Developer_S*.

In addition to the specific concept and relations, the domain ontology which describes the process model must also contain the application-specific SWRL rules that allow rule engines to create sessions and data flows between engineers according to their roles.

2. Phase 2: After the definition of the process model, an enactable process model is created instantiating the defined process model. For the present test case, this instance contains the two working groups and their associated collaboration sessions.

3. Phase 3: The actors-context awareness is taken into account in this phase during which the adaptation process is needed after each action. For example, if an actor joins the system, the system updates the instance of the domain ontology using the proposed API and launch the adaptation process.

CONCLUSION

In this paper, a semantic-driven, adaptive architecture has been developed to manage messaging for collaborative engineering activities within networked enterprises. This architecture is based on a Generic Collaboration Meta-model (GCM) which supports the implementation of session management services. GCM is a domain-independent ontology that can be extended for modeling collaboration knowledge in different application domains. This work provides a framework for session management and adaptive component deployment. Knowledge representation technologies, such as ontologies and SWRL rules, are used to ensure awareness of collaboration situations and to decide when sessions have to be adapted. The proposed architecture provides a generic level of collaboration. It enables the integration of different applications and deals with application-specific information as sub models that are plugged into the framework. The developed prototype system establishes an open and scalable architecture to support inter and intra-enterprise collaboration. Indeed, a process designer defines a process model which represents the actors, their roles, their groups and the associated sessions. The process model is instantiated using the proposed API which is able to check the consistency of the requested actions. The main benefit from this approach is ensuring the continuity of the communication services when changes occur in the process model. The framework supports a dynamic component deployment using the deployment service which uses the produced deployment graph. The type of deployed components depends both on the selected communication model and on the needed communication mode such as synchronous and asynchronous communication. We can conclude that semantic representation and Web semantic technologies are useful to enable dynamic reconfiguration.

The work presented is being tested on real case in the context of the Galaxy project. Future work will consists in performing generic security functionalities and access control, at the communication framework level, which rely on the involved collaborative system.

REFERENCES

Andonoff , E.; W. Bouaziz ; and C. Hanachi. 2007. “A protocol ontology for inter-organizational workflow coordination”. In Proceedings of the 11th East European conference on Advances in databases and information systems, Springer-Verlag, Varna, Bulgaria, 2007. 28-40.

Baudin, V. ; K. Drira ; T. Villemur ; and S. Tazi. 2004. “A model-driven approach for synchronous dynamic collaborative e-learning”. In: C. Ghaoui (Ed.), E-Education applications: human factors and innovative approaches, 2004. 44-65.

Beca, L.; G. Cheng; G.C. Fox; T. Jurga; K. Olszewski; M. Podgorny; P. Sokolowski; T. Stachowiak; and K. Walczak. 1997. “Tango – a Collaborative Environment for the World-Wide Web”. In Northeast Parallel Architectures Center, Syracuse University, New York, 1997.

Brandes, U.; M. Eiglsperger; I. Herman; M. Himsolt; and M.S. Marshall. 2001. “GraphML Progress Report”. In Graph Drawing, 2001. 501-512.

Carstensen, P.H. and K. Schmidt. 1999. “Computer supported cooperative work: New challenges to systems design”, in K. Itoh (Ed.), Handbook of Human Factors, 1999, 619-636.

Chanbert, A.; E. Grossman; L. Jackson; and S. Pietrovicz. 1998. "NCSA Habanero- Synchronous collaborative framework and environment". In Software Development Division at the National Center for Supercomputing Applications, white paper, 1998.

DOE200. 1999. “EMSL DOE2000: Real-time Collaboration Management Project Summary”. ANL, PNNL, NCSA, 20th February, 1999.

Dommel, H.-P. and J.j. Garcia-Luna-Aceves. 1999. “Group Coordination Support for Synchronous Internet Collaboration”. IEEE Internet Computing, 3 (2) (1999) 74-80.

Dourish, P. and V. Bellotti. 1992. “Awareness and coordination in shared workspaces. In Proceedings of the 1992 ACM conference on Computer-supported cooperative work, ACM, Toronto, Ontario, Canada, 1992. 107-114.

Edwards, W.K. 1994. “Session management for collaborative applications”. In Proceedings of the 1994 ACM conference on Computer supported cooperative work, ACM, Chapel Hill, North Carolina, United States, 1994. 323-330.

Edwards, W.K. 2005. “Putting computing in context: An infrastructure to support extensible context-enhanced collaborative applications”, ACM Trans. Comput.-Hum. Interact, 12 (4) (2005), 446-474.

Ganoe, C.H.; J.P. Somervell; D.C. Neale; P.L. Isenhour; J.M. Carroll; M.B. Rosson; and D.S. McCrickard. 2003. “Classroom BRIDGE: using collaborative public and desktop timelines to support activity awareness”. In Proceedings of the 16th annual ACM symposium on User interface software and technology, ACM, Vancouver, Canada, 2003. 21-30.

Garrido, J.L.; M. Noguera; M. Gonzàlez; M.V. Hurtado; and M.L. Rodriguez. 2007. “Definition and use of Computation Independent Models in an MDA-based groupware development process”. Sci. Comput. Program, 66 (1) (2007) 25-43.

Holvoet, T. and Y. Berbers. 2001. “Reflective programmable coordination media”. In: H.R. Arabnia (Ed.), Pdpta'2001: Proceedings of the International Conference on Parallel and Distributed Processing Techniques and Applications, Las Vegas, Nevada, USA, 2001, pp. 1236-1242.

Horrocks, I.; P.F. Patel-Schneider; H. Boley; S. Tabet; B. Grosof; and M. Dean. 2004. “SWRL: A Semantic Web Rule Language Combining OWL and RuleML”. W3C, Member Submission, 2004.

Jang, C.Y.; C. Steinfield; and B. Pfaff. 2000. “Supporting awareness among virtual teams in a web-based collaborative system: the teamSCOPE system”. SIGGROUP Bull, 21 (3) (2000) 28-34.

Lewkowicz, M.; F. Wijnhoven; and A. Draghici. 2008. “Misunderstandings in Global Virtual Engineering Teams: Definitions, Causes, and Guidelines for Knowledge Sharing and Interaction” In: A. Bernard, S. Tichkiewitch (Eds.), Methods and Tools for Effective Knowledge Life-Cycle-Management, Springer, 2008. 145-157.

Marsic, I. 2000. “Real-Time Collaboration in Heterogeneous Computing Environments”. In Proceedings of the The International Conference on Information Technology: Coding and Computing (ITCC'00), IEEE Computer Society, 2000. 222.

Morse, E.L. and M.P. Steves. 2000. “CollabLogger: A Tool for Visualizing Groups at Work”. In Proceedings of the 9th IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises, IEEE Computer Society, 2000. 104-109.

Palmer, J.D.; N.A. Fields; and P.L. Brouse. 1994. “Multigroup Decision-Support Systems in CSCW”, In Computer, 27 (5) (1994) 67-72.

Rodriguez, I.B.; K. Drira; C. Chassot; K. Guennoun; and M. Jmaiel. 2010. “A rule-driven approach for architectural self adaptation in collaborative activities using graph grammars”. Int. J. Autonomic Comput, 1 (3) (2010) 226-245.

Rusinkiewicz, M.; W. Klas; T. Tesch; J. Wäsch; and P. Muth. 1995. “Towards a Cooperative Transaction Model - The Cooperative Activity Model”. In Proceedings of the 21th International Conference on Very Large Data Bases, Morgan Kaufmann Publishers Inc. 1995. 194-205.

Smith, M.K.; C. Welty; and D.L. McGuinness. 2004. “OWL Web ontology Langage Guide”. W3C Recommendation, 2004.

Texier, G. and N. Plouzeau. 2003. “Automatic Management of Sessions in Shared Spaces”, J. Supercomput., 24 (2) (2003) 173-181.

Tomingas, K. and M. Luts. 2010. “Semantic Interoperability Framework for EstonianPublic Sector's E-Services Integration”. In Proceedings of the First Workshop on Ontology Repositories and Editors for the Semantic Web (ORES2010), 2010. 96-100.

Vissers, C.A.; M.M. Lankhorst; and R.J. Slagter. 2004. “Reference Models for Advanced e-services”. In The 3rd IFIP Conference on e-Commerce, e-Business and e-Government, Guarujá – São Paulo – Brazil. 21-24.

Yao, Z.; S. Liu; L. Han; Y.V.R. Reddy; J. Yu; Y. Liu; C. Zhang; and Z. Zheng. 2007. “An ontology based workflow centric collaboration system”. In Proceedings of the 10th international conference on Computer supported cooperative work in design III, Springer-Verlag, Nanjing, China, 2007. 689-698.

Balci, O. and R.G. Sargent. 1981. “A Methodology for Cost-Risk Analysis in the Statistical Validation of Simulation Models.” *Communications of the ACM* 24, No.4 (Apr), 190-197.

PRODUCTION OPTIMIZATION

A DIRECT METHOD FOR ASSESSING THE INFLUENCE OF MATERIAL COUPLES ON THE SWASHPLATE ANGLE OF AXIAL PISTON PUMPS

Adrian Ciocanea
Department of Hydraulics and Hydraulic Machinery
University POLITEHNICA of Bucharest
313 Spl. Independentei, Bucharest, Romania, 060042
E-mail: ciocanea@hydrop.pub.ro

KEYWORDS
Axial piston pumps, swash plate angle, working pressure, material coupling, concurrent engineering.

ABSTRACT

The paper presents an original method that provides exact calculation of the maximum angle value for swash plate axial piston pumps. In order to obtain the angle values only the working pressure and the characteristics of material couples are needed. The method is based on a 3D mathematical model where the piston kinematics and the swash plate are connected through the crank angle and the inclined disc angle. Accordingly, a mechanical model is derived where the piston and cylinder constitute a cylindrical coupling with linear contact. Expressions for the maximum values of the mechanical loads - flexure, shearing and crushing – are considered. The maximum angle value for the swash plate is calculated on the basis of the nominal working pressure and the admissible stresses for the materials used in manufacturing the pistons and the cylinder block. The method can be used both for direct or reverse design procedures and is suitable for introduction to dynamic simulation models. Since this direct method provides results on the functional characteristics and high quality raw material consumption of the product it may be considered as a good tool for product development inside the concurrent engineering procedure.

INTRODUCTION

The permanent progress in volumetric machines is focused both on raising technical performances and lowering manufacturing costs. Raising the working pressure and flow rate implies new materials for improving design parameters. Still, until now there have been no successful models describing the performance of axial piston pumps over the whole operating range hence studies focused on the most relevant issues. Therefore research was carried out in two major directions: assessing volumetric losses due to leakage - (Bergada et al. 2012), (Manring and Zhang 2001) - and fluid compression effect and moment losses due to internal friction. Theoretical models describing the piston friction force are scarce in engineering literature but experimental studies have been published (Vasiliu et al. 2005). A model describing the frictional characteristics of a piston with a ring pack is reported (Kim et al. 2002) considering mixed lubrication. In order to design the cylinder the piston friction force was calculated - a rough estimation - considering a constant friction coefficient (Jaroslav and Ivantysynova 2001). In the paper one observes that high stress is developed across the cylinder and pistons edges, therefore the maximum permissible contact pressure of the related materials limits the radial force value exerted on the piston and hence limits the maximum allowable swash plate angle. Based on a similar approach, Heon-Sul and Hyoung-Eui (2004) derived a formula allowing one to estimate the piston friction force and loss moment of a machine only by knowing the physical dimensions – without experimental tests. Other types of studies were developed in order to assess the efficiency of coating some active machine surfaces in order to obtain higher lubrication - (Yeh-Sun and Sang-Yul 2008), (Yeh-Sun et al. 2006). Also, various material coupling for pistons and cylinder blocks were assessed in order to enlarge the limits of the allowable swash plate angle (Ciocanea, 1995), (Negoita et al. 2010). Taking into account the progress concerning piston and cylinder design geometry (Ivantysynova and Lasaar 2004), the present paper is focused on deriving an original formula that provides calculation of maximum swash plate angle value only by knowing the working pressure and the characteristics of material couples used for manufacturing the piston and cylinder. The method is addressing a missing issue in the product development process of axial piston pumps. Thereby, a mechanical algorithm is available for completing the hydraulic approach of the overall operating behavior of the axial pump and hence results provide more data for a more flexible redesign procedure.

MATHEMATICAL MODEL

In order to determine the piston stroke s as a function of the swashing plate angle γ_0 and the crank angle α, one considers the intersection between a cylinder considered as the cylinder block and the swashing plate plane which is the support for the piston slippers - see Figure 1. The plane equation is:

$$\begin{vmatrix} x & y & z & 1 \\ R & 0 & 0 & 1 \\ 0 & R & -Rtg\gamma_0 & 1 \\ 0 & -R & -Rtg\gamma_0 & 1 \end{vmatrix} = 0 \, , \qquad (1)$$

and one obtains:

$$z = (x - R)tg\gamma_0 . \qquad (2)$$

The cylinder equation is: $x^2 + y^2 = R$ is written using cylindrical coordinates ($x = R\cos\alpha$, $y = R\sin\alpha$) and considering $z = s(\alpha)$ the relation for the piston stroke is:

$$s(\alpha) = Rtg\gamma_0(1 - \cos\alpha) . \qquad (3)$$

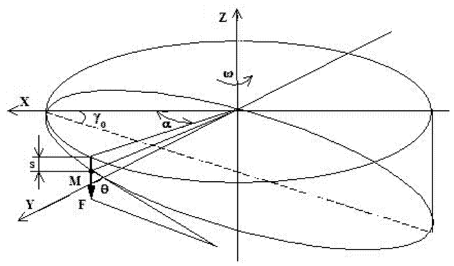


Figure 1 Geometrical data for the cylinder block and swashing plate

If $F(x,y,z) = 0$ is the cylinder equation and $\Phi(x,y,z) = 0$ the swashing plate plane equation:

$$F(x,y,z) = x^2 + y^2 - R^2 = 0$$
$$\Phi(x,y,z) = z - xtg\gamma_0 + Rtg\gamma_0 = 0 \quad , \qquad (4)$$

one determines the relation for tangent angle θ to the mean slippers trajectory in respect with z direction:

$$\frac{x - R\cos\alpha}{\sin\alpha} = \frac{-y + R\sin\alpha}{\cos\alpha} = \frac{z + Rtg_0(1 - \cos\alpha)}{\sin\alpha tg\gamma_0}, \qquad (5)$$

and the equation line, which contains point M and is parallel to z direction, is given by:

$$\frac{x - R\cos\alpha}{0} = \frac{-y + R\sin\alpha}{0} = \frac{z + Rtg_0(1 - \cos\alpha)}{1}. \qquad (5')$$

The angle θ between the lines given by equations (5)-(5') is:

$$\cos\theta = \pm\frac{\sin\alpha tg\gamma_0}{\sqrt{1 + \sin^2\alpha tg^2\gamma_0}} \; ; \; tg\theta = \frac{1}{tg\gamma_0 \sin\alpha} . \qquad (6)$$

MECHANICAL MODEL

The mechanical model considers the piston and the cylinder constituting a cylindrical coupling with linear contact. Under the action of the effective force $F_e = F/tg\theta$ - see Figure 2 – where $F = \pi \cdot d^2_{pist} \cdot p_0/4$ and using relation (6):

$$F_e = \frac{\pi d^2{}_{pist}}{4} p_0 tg\gamma_0 \sin\alpha \, , \qquad (7)$$

where p_0 is the nominal working pressure considered as constant, the piston is strained at flexure, shearing and crushing.

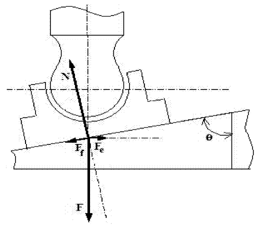


Figure 2 The diagram of the forces acting on the piston

This hypothesis simplifies the real piston loading by neglecting lateral forces. Still, the loading diagram available in Figure 3 represents a good approximation and provides good accuracy of results. In fact, one considers that the piston and the cylinder form a coupling with intermediary film that seems to represent a limit situation.

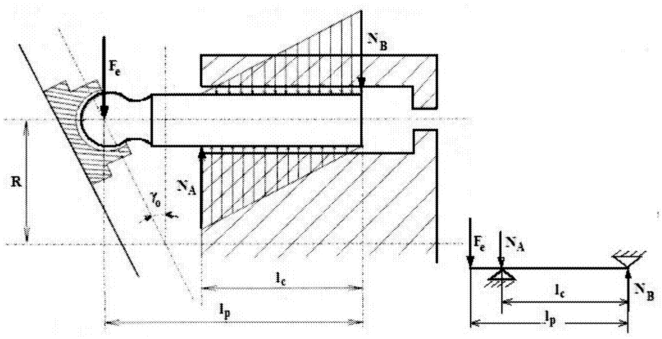


Figure 3 The loading diagram

In real regime, because of the suction and delivering under pressure process, in the suction phase the film must be considered as hybrid - dry hydrodynamic since at this moment it is damaged. Therefore, the model is derived in poor functional condition.

Maximum strain evaluation

Using the diagram from Figure 3, one can evaluate the maximum stresses that strain the piston that is considered as a continuous beam with simple bearing.

The contact pressure

The variation of the contact pressure between the piston and the cylinder $p_c = F_2/(l \cdot d_{pist})$ depends on the instant contact length between piston and cylinder $l(\alpha) = l_c - s(\alpha)$ where α is the rotating angle of the cylinder block and $s(\alpha)$ is the piston stroke – see Figure 4 - derived from geometric conditions: $s(\alpha) = Rtg\gamma_0 (1-\cos\alpha)$.

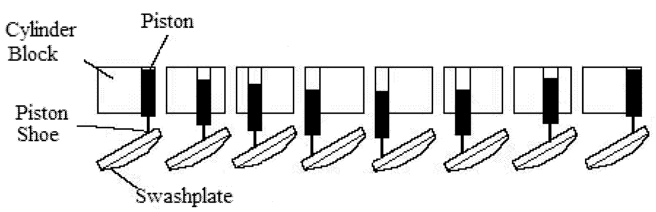


Figure 4 The position of the piston in the cylinder

Introducing (7) and the above relations one obtains the contact pressure:

$$p_c(\alpha) = \frac{\pi d_{pist} p_0 tg\gamma_0}{4} \cdot \frac{\sin\alpha}{l_c - Rtg\gamma_0(1-\cos\alpha)} . \qquad (8)$$

Two conditions are used in order to obtain the maximum value for the contact pressure function: $dp_c / d\alpha = 0$ and $d^2p_c / d\alpha^2 < 0$. From the first condition one obtains:

$$\cos\alpha = -\frac{Rtg\gamma_0}{l_c - Rtg\gamma_0} = \cos\alpha_0 \qquad (9)$$

and from the second condition one verifies that $\alpha = \alpha_0$ gives the maximum value for the contact pressure function - relation (8) - if considering $2Rtg\gamma_0 << l_c$:

$$\frac{d^2 p_c}{d\alpha^2} = 2rl_c tg\gamma_0 \frac{l_c(l_c - 2Rtg\gamma_0)}{l_c - Rtg\gamma_0}\left(\frac{\sqrt{1-\frac{2R}{l_c}tg\gamma_0}}{1-\frac{R}{l_c}tg\gamma_0} - 1\right) . \qquad (10)$$

Taking into account relations (8) and (9) one obtains:

$$l_c = tg\gamma_0\left(R + \sqrt{R^2 + \frac{\pi^2 p_0^2}{16 p_c^2} d_{pist}^2}\right) . \qquad (11)$$

The flexure

According to Figure 3 one calculates the bearing reaction $N_A = F_e \cdot l_p/l_c$ and $N_B = F_e \cdot (l_p - l_c)/l_c$ and the flexure momentum $M(\alpha) = F_e \cdot (l_p - l_c) = F_e(\alpha)s(\alpha)$. Using relations (3) and (7) the flexural momentum is:

$$M(\alpha) = \frac{\pi p_0 d_{pist}^2 Rtg^2\gamma_0}{4} \sin\alpha(1-\cos\alpha) . \qquad (12)$$

Using the same algorithm as above, the two conditions for obtaining the maximum value for the flexural moment are: $dM/d\alpha = 0$ and $d^2M/d\alpha^2 < 0$. Hence from the first condition one obtains the values for the rotating angle of the cylinder block: $\alpha_1 = 0^0$ and $\alpha_2 = 120^0$. From the second condition one finds that the latter solution is the acceptable one since $(d^2M/d\alpha^2)|_{\alpha 2 = 120^0} = \sin\alpha_2(4\cos\alpha_2 - 1) < 0$. Introducing the above value of the rotating angle in relation (12) the maximum flexural moment is obtained:

$$M_{\max} = \frac{3\sqrt{3}\pi}{16} p_0 d_{pist}^2 Rtg\gamma_0 . \qquad (13)$$

On the other hand, the relation for the bearing reaction $N_A = F_e(\alpha) \cdot l_p/l(\alpha)$ as function of the rotating angle of the cylinder block is:

$$N_A = \frac{\pi d_{pist}^2}{4} p_0 l_p tg\gamma_0 \frac{\sin\alpha}{l_c - Rtg\gamma_0(1-\cos\alpha)} . \qquad (14)$$

The maximum value for the reaction force N_A is obtained from the condition $dN_A / d\alpha = 0$ where the solution is:

$$\cos\alpha_3 = -\frac{Rtg\gamma_0}{l_c - Rtg\gamma_0} . \qquad (15)$$

The condition $(d^2N_A / d\alpha^2)|_{\alpha = \alpha 3} < 0$ is satisfied and one considers α_3 as the solution for the maximum value of the reaction force:

$$N_{A\max} = \frac{\pi d_{pist}^2 p_0 l_p}{4} \frac{1}{\sqrt{l_c^2 - 2l_c Rtg\gamma_0}} . \qquad (16)$$

THE MAXIMUM ANGLE VALUE OF THE SWASHPALTE

The maximum angle value of the swash plate can be derived with respect to the nominal working pressure p_0 and the admissible stresses for the materials used in manufacturing the pistons and the cylinder block. One considers the effect of all the above strains in the hypothesis that the assembly has to fulfill resistance conditions. Therefore the maximal tangential stresses according to relation (16) is:

$$\tau_{\max} = \frac{p_0 l_p}{\sqrt{l_c^2 - 2l_c Rtg\gamma_0}} \langle \tau_{at} , \qquad (17)$$

where τ_{at} is the admissible tangential effort. In Tacking into account the hypothesis that $l_p = l_c$ (often l_p/l_c = 1,1…1,25) and introducing the ratio:

$$k_\tau = \frac{p_0}{\tau_{at}} , \qquad (18)$$

finally the relation for l_c is:

$$l_c = \frac{2Rtg\gamma_0}{1-k_\tau^2} . \qquad (19)$$

Using relations (11) and (19) one eliminates l_c and by introducing a new ratio:

$$k_p = \frac{p_0}{p_{ac}} , \qquad (20)$$

where p_{ac} is the admissible contact pressure, one obtains a relation between two relevant geometrical parameters:

$$\frac{d}{R} = \frac{8k_\tau}{\pi k_p(1-k_\tau^2)} . \qquad (21)$$

Using relation (21) and introducing the ratio:

$$k_\sigma = \frac{p_0}{\sigma_{af}} , \qquad (22)$$

where σ_{af} is the admissible flexural stress, the result is:

$$\frac{d}{R} = 6\sqrt{3}k_\sigma tg^2\gamma_0 . \qquad (23)$$

Finally, eliminating the ratio d / R between relations (21) and (23) one obtains:

$$tg\gamma_{0\max} = \sqrt{\frac{4k_\tau}{3\pi\sqrt{3}k_p k_\sigma(1-k_\tau^2)}} . \qquad (24)$$

Using relation (24) one can calculate the maximum angle value of the swash plate without knowing the constructive pump parameters. For this it is sufficient to know the material coupling used for manufacturing the pistons and cylinder block and the nominal working pressure. Consequently, it is possible to evaluate the appropriate quality of the materials from which the pumps are made of. Moreover, if relation (24) is introduced to dynamic simulation systems it can provide evaluations on overall costs of a new/redesigned product.

CASE STUDY

One considers an axial piston pump with swash plate, working at p_0 = 300 bar, with a cylinder block made of bronze - 20% Pb – and pistons made of nitride steel – classic case. For these materials there are the following admissible stresses: p_{ac} = 50 daN/cm^2; σ_{af} = 2000 daN/cm^2; τ_{at} = 900 daN/cm^2. For the above values the coefficients from relations (18), (20), (22) are calculated: k_τ = 0,335; k_p = 6,4; k_σ = 0,16. Using relation (24) finally yields the maximum value for the swash plate: tg γ_{0max} = 0,339 and $\gamma_{0max} = 18^0 30'$. A final conclusion is that for this case study the working pressure must not exceed 320 bar and the maximum value of the swash plate is 19^0.

For a better assessment of the method, a second case study is considered according to Figure 5 where the two regions *A* and *B* have different functional parameters.

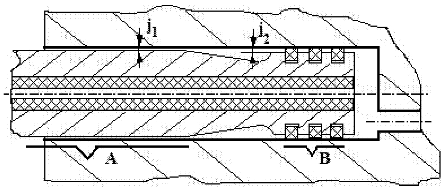


Figure 5 The geometry of the piston and cylinder

Surface *A* has a slide role and is made of a bronze dust layer consisting of spherical particles with a diameter of about 60-160 μm (9% - 11% St); a second layer consists of 75% PTFE and 25% molybdenum . Surface *B* has PTFE sleeves and the cylinder surface is made of nodular graphite iron. The performances for this case study are: mean contact pressure p_{ac} = 150 daN/cm^2; maximum working temperature: 280^0C; dry friction coefficient: 0,02; slide clearance j_1 = 8-15 μm; friction clearance j_2 = (1.25-1.75) j_1 ; hydromechanical efficiency increase: 2-3%; endurance increased by 30%. Redoing the calculation for the above values, the coefficients from relations (18), (20), (22) are: k_τ = 0,335; k_p = 2,133; k_σ = 0,16.

Using relation (24) finally yields the maximum value for the swash plate: $\gamma_{0max} = 28^0$. As a general conclusion one can see that the maximum angle value is limited by the quality of the material coupling. The variation of the maximum angle value for the swash plate is shown in Figure 6.

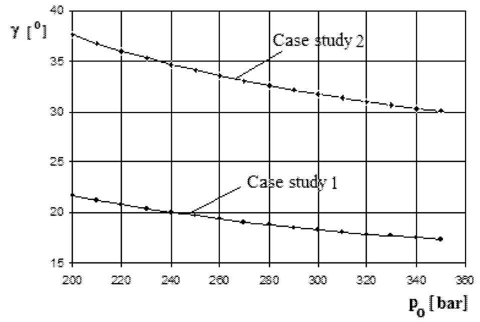


Figure 6 Values of the swash disk angle for the two case studies

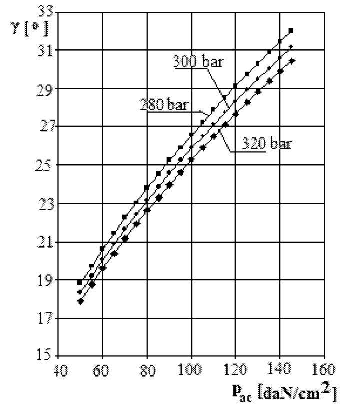


Figure 7 Swash disk angle variation for various values of admissible contact pressure (σ_{af} = 2000 daN/cm^2; τ_{af} = 900 daN/cm^2)

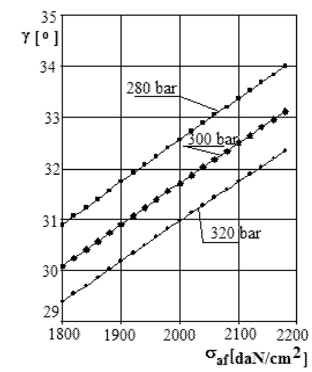


Figure 8 Swash disc disk angle variation for various values of admissible flexural efforts (τ_{at} = 900 daN/cm^2; p_{ac} = 150 daN/cm^2)

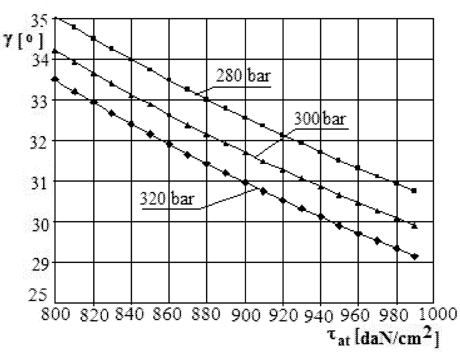


Figure 9 Swash disk angle variation for various values of the admissible tangential effort

(σ_{af} = 900 daN/cm^2; p_{ac} = 150 daN/cm^2)

Analyzing the numerical simulation results presented in Figures 6 to 9 one can observe the following:

- the solution presented in case study 2 provides a higher maximum angle for the swash plate but with increased manufacturing costs;
- the most relevant increase of the swash plate angle is obtained by providing a coupling material with high admissible contact pressure rather than high admissible flexure or tangential efforts;
- considering a variation of 20% for the accepted values of admissible stresses σ_{af} and τ_{at} (and preserving the best value p_a =150 daN/cm^2 as presented in case study 2) one observes that the maximum variation of the swash plate angle (for every working pressure value) is about 3^0 for the working pressure interval 280-320 bar if τ_{at} is kept constant and about $4^0 30'$ if σ_{aft} is kept constant; hence from this point of view, a better choice is to use a piston material with a higher tangential admissible effort rather than flexural admissible one;
- the variation of the swash plate angle against the admissible tangential stresses γ (τ_{at}) has a descending slope (the slope of the flexure admissible efforts curves γ (σ_{af}) is ascending), i.e when choosing the piston material it is necessary to evaluate an optimum value and not only to consider the latter conclusion;
- the data used for assessing the present method can be extended to higher values by taking into account real design solutions, technology limitations and new material availability.

There are also other methods for increasing the angle of the swash plate. One of them consists in using rings for the pistons and the steel cylinder sleeve. In this case one obtains angles of about 25^0-40^0 and the piston is short, double linked and the external surface is curved; therefore this type of piston cannot be used for swash plate axial pumps.

The case studies presented above are relevant for the effectiveness of the proposed mechanical method concerning manufacturing costs when the material characteristics are known.

CONCLUSION

A direct method that provides exact calculation of the maximum angle value for the swash plate of axial piston pumps is proposed. Using a coupled mathematical and mechanical model one can calculate the angle only by knowing the working pressure and characteristics of the material coupling for piston and cylinder. A mechanical algorithm is available for completing the dynamic simulation systems for axial pump manufacturing. Results provide information for a more flexible redesign procedure. By analyzing the results of two case studies one observes that:

- the relation for calculating the maximum angle of a swash plate is available if three coefficients are derived - k_{cp}, k_τ, k_σ;
- a better solution for the piston and cylinder design is the one using 2 regions with different characteristics in order to increase the admissible contact pressure value;
- the most relevant increase of the swash plate angle is obtained by providing a coupling material with high admissible contact pressure rather than higher admissible flexure or tangential efforts;
- the data used for assessing the present method can be extended to higher values by taking into account real design solutions, technology limitations and new material availability;

REFERENCES

Bergada, J.M.; S. Kumar; D. Dl. Davis; J. Watton. 2012. "A complete analysis of axial piston pump leakage and output flow ripples." Applied Mathematical Modelling, 36, 1731-1751.

Ciocănea, A. 1995. "The maximum angle value of the inclined disc for the adjustable axial piston pumps". *Proceedings of the 1995 International Conference of hydropneumatical systems and drives* (Timisoara, Romania). 1, 98-104.

Heon-Sul, J. and K. Hyoung-Eui. 2004. "On the Instantaneous and Average Piston Friction of Swash Plate Type Hydraulic Axial Piston Machines." *KSME International Journal*, Vol.18, No.10, 1700-1711.

Ivantysyn, J.; and M. Ivantysynova. 2001. *Hydrostatic Pumps and Motors.* Akademia Books International, ISBN 81-85522-16-2.

Ivantysynova, M and R. Lasaar. 2004. "An Investigation into Micro- and Macro-Geometric Design of Piston/ Cylinder Assembly of Swash Plate Machines." International Journal of Fluid Power, Vol. 5, No.1, 23-36.

Kim, J.Y.; J.W. Kim; M.R. Cho; D.C.Han. 2002. "Frictional Characteristics of Piston Ring Pack with Consideration of Mixed Lubrification: Parametric Investigation." *KSME International Journal*, Vol.16, No.4, 468-475.

Manring, N.D. and Y. Zhang. 2001."The improved volumetric efficiency of an axial-piston pump utilizing a trapped-volume design." *Journal of Dynamic System. Measurement and Control*, ASME 123, 479–487.

Negoiță, C.G.; D. Vasiliu; N. Vasiliu; C. Călinoiu. 2010. "Modeling, Simulation and Identification of the Servo pumps.", *Proceedings of the 25th IAHR Symposium on Hydraulic Machinery and Systems*, ISBN 978-606-554-134-4, 978-606-554-135-1 (Timişoara, Romania), 417-424.

Vasiliu, N.; and D. Vasiliu. 2005. *Fluid Power Systems.* Technical Press House Bucharest, ISBN 973-31-2249-1.

Yeh-Sun H. and L. Sang-Yul. 2008. "A Comparative Study of Cr-X-N (X=Zr, Si) Coatings for the Improvement of the Low-Speed Torque Efficiency of a Hydraulic Piston Pump." *Metals and Materials International*, Vol. 14, No. 1, 33-40.

Yeh-Sun H.; L. Sang-Yul ; K. Sung-Hu; L. Hyun-Sik. 2006. “Improvement of the Low-Speed Friction Characteristics of a Hydraulic Piston Pump by PVD-Coating of TiN.” *Journal of Mechanical Science and Technology (KSME Int. J.)*, Vol.20, No. 3, 358-365.

BIOGRAPHY

ADRIAN CIOCĂNEA was born in Bucharest, Romania and was admitted to the University POLITEHNICA of Bucharest were he earned a degree in mechanical engineering in 1985. He worked for a Helicopter Company in Brasov, and after a few years he joined the Department of Hydraulics and Hydraulic Machinery at University POLITEHNICA of Bucharest were he is working as associate professor. His main interest fields are the numerical integration of Navier-Stokes equations, turbomachinery hydro-aerodynamics and renewable sources of energy.

CONCURRENT ENGINEERING BY HARDWARE-IN-THE-LOOP SIMULATION WITH R-T WORKSHOP

Radu Puhalschi
Daniela Vasiliu
Daniel Dragos Ion Guta
Bogdan Mihalescu

University POLITECHNICA of Bucharest
313 Splaiul Independenței, Bucharest, Romania, 060042
E-mail: {radupuh|vasiliu1958|iongutadragos|bmihalescu}@gmail.com

KEYWORDS
Concurrent engineering, hardware-in-the-loop simulation, speed governors, fine tuning.

ABSTRACT

The paper presents a way of using hardware-in-the-loop simulation for the design of speed governors for hydraulic turbines. The mathematical model of a Kaplan turbine and the electrical power generator are built in a numerical simulation software (Simulink, AMESim, LabVIEW etc.), and the resulting system interacts with an actual electrohydraulic servomechanism. This allows an experimental test of the whole speed control system in a very close environment to the actual operating conditions without the need of an actual turbine and power generator on the test platform.

INTRODUCTION

The goal of concurrent engineering is to reduce project delivery time by overlapping sequential activities. Hardware-in-the-loop simulation (HIL in short) is a recently developed technique that is used in the development and test of complex real-time embedded systems which helps greatly in this regard by facilitating the different phases of the design and prototyping process. HIL simulation provides an effective platform by adding the peculiarities of the plant under control to the test platform. The complexity of the plant under control is included in test and development by adding a mathematical representation of all related dynamic systems.

These mathematical representations are referred to as "plant simulation". The tested system interacts with this plant simulation. This is done via electrical emulation of the output of sensors and actuators. The outputs act as an interface between the plant simulation and the system under test.

The value of each sensor output is controlled by the plant simulation and is read by the real system under test (feedback). Likewise, the system under test outputs sensor signals to communicate its behavior to the plant simulation. Changes in the control signals result in changes to variable values in the plant simulation.

The main advantages of HIL simulations are reduced costs, and full control over the test environment. In many cases, the plants that the tested components are supposed to interact with are complex and expensive systems. It is not always possible, or economically feasible to perform tests on the actual plant, nor to build an exact replica on the test platform. In such cases, a high-performance HIL simulation system can usually be obtained for a fraction of the cost. (Andrade et al. 2010). Also, especially in fields where safety is paramount (like aeronautical engineering, nuclear industry etc.), sometimes components need to be tested in conditions that would cause great damage to the plant. In such situations it is obviously more convenient to simulate the plant behavior. Currently, there are several different established HIL solutions on the market.

National Instruments offers integrated solutions that include hardware (the PXI series of real-time machines and their numerous accessories) as well as software (Conway and Watts 2003), both for developing real-time applications (the graphical programming environment LabVIEW, but AMESim models are also supported) and running them (the NI real time operating system). Having an all-in-one solution has some obvious advantages concerning the ease of purchasing and deploying a complete real-time simulation platform (Vasiliu 2010) but this comes at the cost of flexibility, as integrating non-NI components in the system raises some problems.

Another real-time solution that has rapidly gained popularity is dSPACE, developed by the German company dSPACE Inc. This integration environment offers both high-performance hardware and software solutions for running real-time simulations, which can work with models developed in a large variety of software (including Simulink and AMESim). The biggest disadvantage is the lack of flexibility. dSPACE systems come preconfigured from the producer according to a set of specifications, and the user is unable to make any changes to the test platform's architecture (Martens and Ross 2011).

The Real-Time Workshop (rebranded Simulink Coder starting with Matlab r2011) extension for Simulink, developed by MathWorks is probably the most accessible real time simulation platform. It is a software only solution, but it can run on virtually any hardware, being both Windows (32 bit only) and UNIX (including dedicated real-time UNIX versions). The biggest drawback of the

Windows implementation (Real-Time Windows Target) is that due to running on a generic operating system as opposed to a dedicated real-time one, it cannot achieve true real-time simulation response (about 10ms delay) so it's not the best solution for simulating fast systems.

TURBINE-GENERATOR MODEL

The system chosen to demonstrate the concept of HIL simulation is the speed governor of a Kaplan turbine. Being a rather slow system, it is largely unaffected by the slight operating system delays mentioned in the previous paragraph.

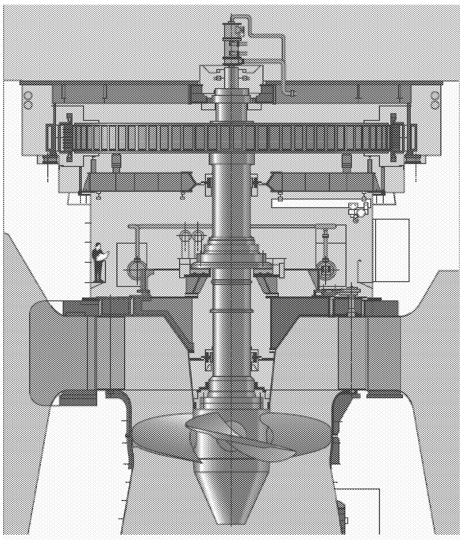


Figure 1 Kaplan turbine (courtesy Voith-Siemens)

Varying the opening of the wicket gate is done by changing the position of its blades and allowing the control of the water flow entering the turbine chamber, which in turn controls the turbine's speed, and the power transmitted to the generator.
Moving the wicket gate blades is done with two linear servomotors, commanded electrically by the speed governor. One such servomotor is used as the tested system for this paper.
In practice, Kaplan turbines also have an additional control loop that adjusts the angle of the rotor blades in order to ensure a high efficiency at any operating parameters, but modeling it is beyond the scope of this paper.
Studying the behavior of turbine systems with forced conduit is best done considering the following simplification hypotheses (Kundur 1994; Ogata 2009):
-the hydraulic resistance can be ignored;
-the water is incompressible;
-the forced conduit is not elastic;
-the water speed is proportional to the wicket gate opening and the square root of the head;
-the power of the turbine is proportional to the product of the head and flow.
The system's behavior depends on:
-water speed;
-the power of the turbine;
-the acceleration of the water column.
The water speed can be calculated as follows:

$$U = K_u G\sqrt{H}$$

Here
U= water speed;
G= wicket gate position;
H= hydaulic fall at the wicket gate;
K_u = proportional constant.
For small variations around a given point:

$$\Delta U = \frac{\partial U}{\partial H}\Delta H + \frac{\partial U}{\partial G}\Delta G$$

Considering the two equations above, we get:

$$\frac{\Delta U}{U_0} = \frac{\Delta H}{2H_0} + \frac{\Delta G}{G_0}$$

or normalized:

$$\Delta\overline{U} = \frac{1}{2}\Delta\overline{H} + \Delta\overline{G}$$

The power of the turbine can be calculated as follows:

$$P_m = K_p HU$$

Linearizing this equation for small variations around a given point and considering that

$$P_{m0} = K_p H_0 U_0$$

we get

$$\frac{\Delta P_m}{P_{m0}} = \frac{\Delta H}{H_0} + \frac{\Delta U}{U_0}$$

or normalized:

$$\Delta\overline{P}_m = \Delta\overline{H} + \Delta\overline{U}$$

Replacing ΔU and ΔH we get

$$\Delta\overline{P}_m = 1.5\Delta\overline{H} + \Delta\overline{G}$$

$$\Delta\overline{P}_m = 3\Delta\overline{U} - 2\Delta\overline{G}$$

The acceleration of the water column is given by the following equation:

$$(\rho LA)\frac{d\Delta U}{dt} = -A(\rho a_g)\Delta H$$

Here
L= length of the conduit;
A= section area;
ρ= water density;
a_g = gravitational acceleration;
ρLA = mass of water in the conduit;
ρ a_gΔH = pressure variaton in the wicket gate.
We get

$$\frac{LU_0}{a_g H_0}\frac{d}{dt}\left(\frac{\Delta U}{U_0}\right) = -\frac{\Delta H}{H_0}$$

or normalized

$$T_w \frac{d\Delta\overline{U}}{dt} = -\Delta\overline{H}$$

where

$$T_w = \frac{LU_0}{a_g H_0}$$

T_w is called the starting time constant for water and represents the time needed for the water column to reach the velocity U_0 for a head value of H_0.
Replacing d/dt with the Laplace operator we get:

$$T_w s\Delta\overline{U} = 2(\Delta\overline{G} - \Delta\overline{U})$$

or

$$\Delta\overline{U} = \frac{1}{1 + \frac{1}{2}T_w s}\Delta\overline{G}$$

The transfer function for the ideal turbine model is:

$$H(s) = \frac{\Delta\overline{P}_m}{\Delta\overline{G}} = \frac{1 - T_w s}{1 + 0.5T_w s}$$

According to experimental identification performed on a similar model (Ion Guta Dragos 2008), the transfer function for the complete turbine-generator system is:

$$P(s) = \frac{\Delta\omega}{\Delta G} = \frac{1 - T_w s}{1 + 0.5T_w s} \cdot \frac{k_w}{T_M s + K_D}$$

Here,
T_w = starting time constant for water;
k_ω = transfer coefficient for the process;
T_M = mechanical time constant of the generator;
K_D = electrical network adjustment factor ($0 \leq K_D < 1$).
Extreme values are:
$K_D = 0$ for the system powering an isolated consumer;
$K_D = 1$ for the system coupled to an infinite power network.

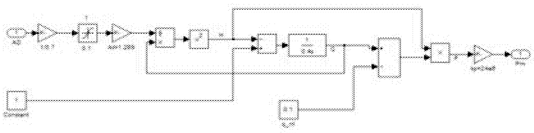


Figure 2 Turbine Simulink Model

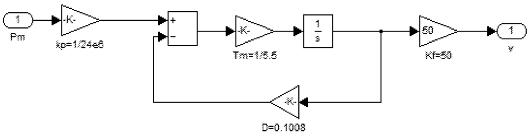


Figure 3 Generator Simulink Model

The speed governor is programmed to ensure that, upon starting the turbine-generator assembly, usable current of 50 Hz frequency is produced in the shortest possible time. It consists of a standard PID controller with a bypass system that sends out the optimum command signal (corresponding to the established 25% start wicket gate opening) until the generator frequency reaches 40...45 Hz and only engages the PID unit afterward (Vasiliu et al. 2007).

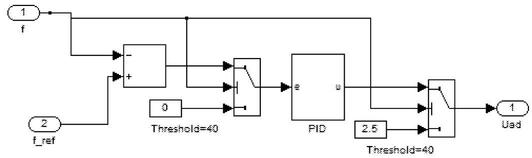


Figure 4 Speed governor Simulink model

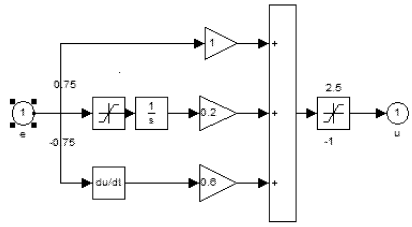


Figure 5 PID Simulink Model

TEST PLATFORM ARCHITECTURE

The test platform consists of an National Instruments PXI-1031 computer, with the embedded NI-PXI 6251 data acquisition board, and an electrohydaulic servomechanism (Vasiliu and Vasiliu 2005).

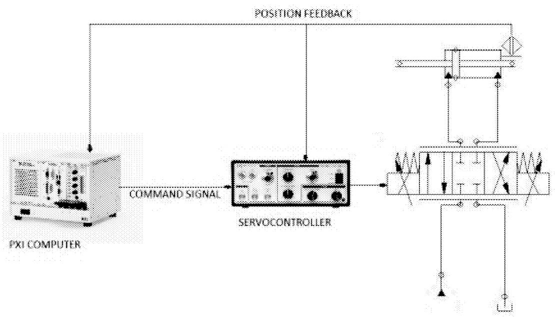


Figure 6 Test platform overall diagram

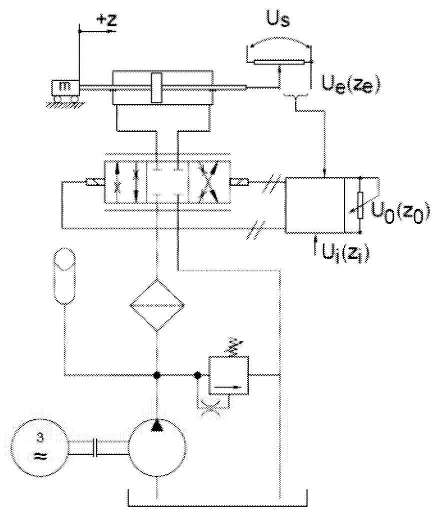


Figure 7 Test bench hydraulic diagram

For this test, the PXI computer is running Windows XP, Matlab R2008b with Real-Time Workshop v3.5 and Real-Time Windows Target. The Simulink model from Figure 11 has been built and deployed on the embedded real-time simulation system (Real -Time Windows Target).

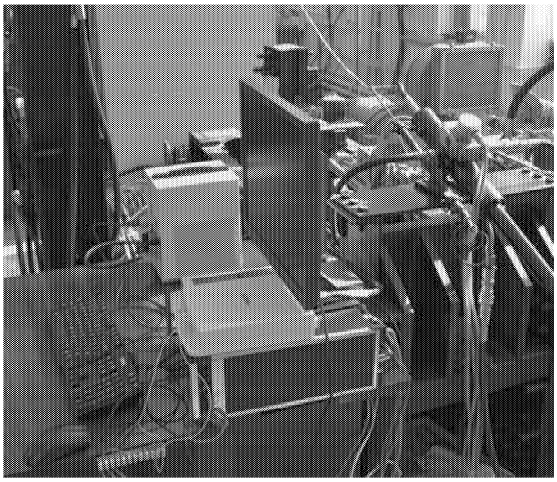


Figure 8 Side view of the test platform

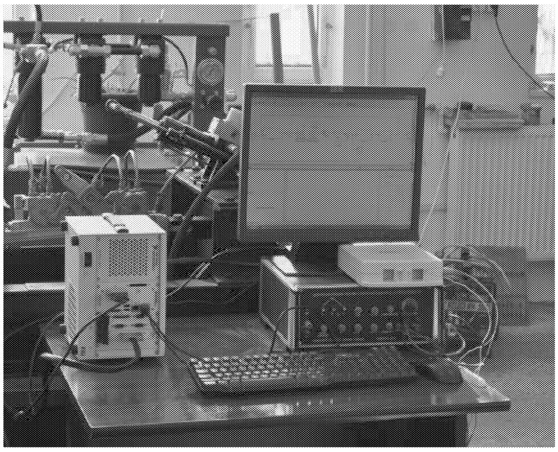


Figure 9 Front view of the test platform

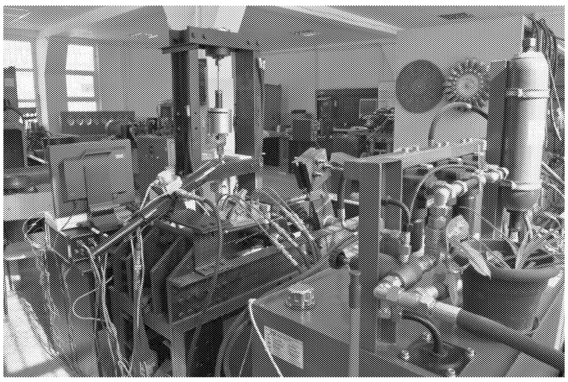


Figure 10 Rear view of the test platform

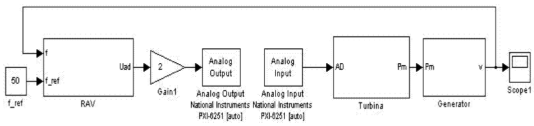


Figure 11 HIL simulation model

The analog input of the data acquisition board was connected to the analog servocontroller of the servomechanism, feeding the command signal from the speed governor.The analog output of the data acquisition board was connected to a transducer measuring the position of the hydraulic piston, and therefore feeding the value of the 'wicket gate opening' into the turbine model. The response of the system is shown below.

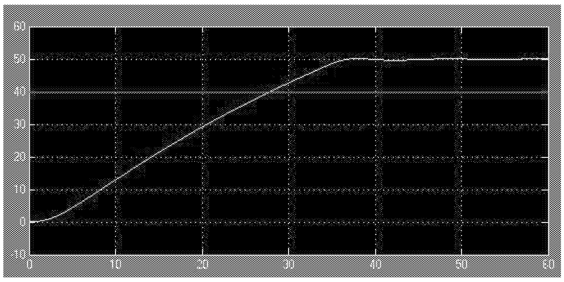


Figure 12 The simulated response of the system

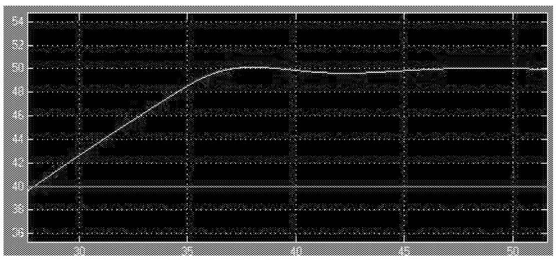


Figure 13 Zoomed-in view of the simulated response

The response is very similar to the experimental results obtained during the set up of a similar speed governor at Ramnicu Valcea power plant (Vasiliu et al. 2006).

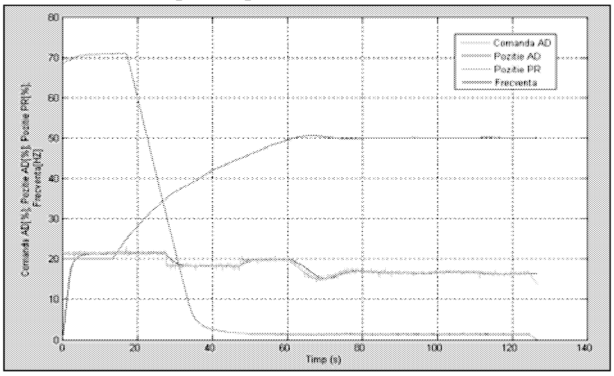


Figure 14 Experimental behavior of the hydropower unit

CONCLUSION

The results of the simulation are very accurate. The hardware-in-the-loop method has provided a way to perform the desired testing of the servomechanism under very similar conditions to the working ones, all of that using simple and inexpensive testing equipment, because there is no need for an actual turbine or generator to be present on the test platform. The co-simulation possibilty (ION GUTA 2008) with AMESim, LabVIEW and other simulation environmens enlarges the application area for any medium speed control process.

The possibility of performing comprehenisve tests in a fully controlled enviroment greatly helps in streamlining research and design acivities. The need for lenghty and costly field tests is practically eliminated since the conditions can be duplicated with accuracy on the test platform, and can often be controlled with much greater precision than on a field test. This also means that test results can be analyzed and interpreted in a timely manner, which leads to a shorter time needed to address any eventual issues.

Also, it is much easier to run multiple testing programs in parallel, making the analyisis of different aspects of the design a *concurrent* rather than sequential process, since duplicating the test platform is merely a matter of ensuring access to a shared software model of the plant.

REFERENCES

Andrade, C., Dufour, C. and Belanger, J. 2010. *RTLab Real-Time Simulation Technologies in Education: a Link to Modern Engineering Methods and Practices*. Proceedings of the 11th International Conference on Engineering and Technology Education INTERTECH 2010.

Conway J. and Watts, S. 2003. *A software engineering approach to LabVIEW*. Prentice Hall Professional.

Ion Guta, D.D. 2008. Researches on the Real Time Simulation of the Fluid Power Systems. PhD Thesis, University POLITEHNICA of Bucharest.

Kundur, P. 1994. *Power System Stability and Control*. McGraw-Hill, Inc.

Mertens F. and Ross H.. 2011. *Fast and Economically Efficient from Idea to Prototype*. MED Engineering, dSPACE GmbH.

Ogata, K. 2009. *Modern Control Engineering (5th edition)*. Prentice Hall.

Vasiliu, C. 2011. *Automotive Powertrain HIL by LabVIEW and LMS IMAGINE AMESim.* PhD Thesis, University POLITEHNICA of Bucharest.

Vasiliu, N., Vasiliu, D. 2005. *Fluid Power Systems*. Technical Press House Bucharest.

Vasiliu, N., Calinoiu, C., Vasiliu, D., Manea, I. 2007. *Performance Identification of a new Type Speed Governor for Kaplan Turbines*. Proceedings of IMECE07 2007 ASME International Mechanical Engineering Congress and Exposition, November 11-15, 2007, Seattle, Washington, U.S.A.

*** 2010. *Matlab - User' Guide*. MathWorks, Natick, MA.

*** 2010. *Simulink - User' Guide*. MathWorks, Natick, MA.

*** 2011. *Real-time Simulation Technologies: Principles, Methodologies, and Applications.* MathWorks, Natick, MA.

*** 2012. *HIL Simulation for Everybody.* www.dspace.com

BIOGRAPHIES

RADU PUHALSCHI graduated in Applied Computer Science from University POLITEHNICA of Bucharest in 2009, and a MD in Advanced Hydraulic and Pneumatic Systems in 2011. He began a PhD research work on real-time HIL simulation of hydraulic systems at the Fluid Power Laboratory from the Power Engineering Department of the University POLITEHNICA of Bucharest.

DANIELA VASILIU graduated in mechanical engineering from University POLITEHNICA of Bucharest in 1981. After a few years of industrial stages in the field of fluid power systems, and some research stages in I.N.S.A. TOULOUSE she became PhD in Fluid Mechanics (1997) and state professor (2001), leading the CAD/CAE Laboratory from the Power Engineering Faculty of the University POLITEHNICA of Bucharest. She worked always for the industry, as project manager or scientific advisor in the field of numerical simulation.

DRAGOS DANIEL ION GUTA, Ph.D. graduated in mechanical engineering from University POLITEHNICA of Bucharest in 2002. After a MD in Advanced Hydraulic and Pneumatic Systems he became PhD in Fluid Power Systems in 2008. He is currently working as scientific researcher and associated lecturer in the modeling and real time simulation of the fluid power systems at University POLITEHNICA of Bucharest, Energy and Environmental Protection Centre.

BOGDAN MIHALESCU graduated in Hydropower Engineering from University POLITEHNICA of Bucharest in 2007. He become assistant professor at the same university and began a PhD stage in the fluid control systems.

SIMULATION SUPPORTING CONCURRENT RESEARCH ENGINEERING
ELECTRIFYING AUXILIARIES FOR LOW CARBON CONVENTIONAL VEHICLES

Claudia Mathis, Alfred Steinhuber, Raul Estrada Vazquez
Electronic and Technology Management
University of Applied Sciences FH-JOANNEUM
Werk VI Strasse 46, 8605 Kapfenberg
Austria
E-mail: {claudia.mathis|alfred.steinhuber|raul.estradavazquez}@fh-joanneum.at

KEYWORDS
Concurrent engineering, virtual prototyping, multi physics simulation, system function development,
auxiliary electrification

ABSTRACT

As embedded systems have grown more complex and, consequently also in size over the past years, this fact has to be taken account for in development as in research. On the one hand this has the effect that research and development teams are constituted by many different experts collaborating and working concurrently. This fact is placed emphasis on, as national and/or EC funded research projects are required to be cooperative. On the other hand simulation is meanwhile a crucial means to cope complexity in development. It supports especially overall system functions development and their optimization as well as it allows early decisions in projects. EE-VERT is an example of a cooperative EC funded project, which targets 10-12% in reduction in fuel consumption for conventional road vehicles. A main part of its concept is the electrification of auxiliary systems, operating them on demand and supplying them, whenever possible, with recovered brake and CO2-neutral energy (Ward et al 2008, Abele 2009). Within EE-VERT, proof of concepts by simulation in parallel to auxiliary (component) development is a main issue. Thus auxiliary electrification has been taken as an example along this paper to figure out benefits of simulation support in research engineering. Final simulation results show that the auxiliary electrification concept contributes with 10-12% about as big as the EE-VERT overall target.

INTRODUCTION

Many of European funded projects follow the strategy that they are classified ***cooperative***, meaning that partners of various nations and different specialization including small, medium and large enterprises as well as dedicated research and educational institutions are expected to collaborate.
On the one hand research projects also grew ***more complex*** taking follow up to applied industry development. As a consequence, research and development teams have many different specialists collaborating, ending up ***concurrently engineering*** as it is state of the art.

The EE-VERT project is a successful example of cooperative and concurrent research engineering. EE-VERT is an EC funded project of the 7th framework program[1], and is assigned to *Theme Greening* supporting the global objective of greenhouse gas reduction (European Environment Agency 2008). Thus EE-VERT targets an overall reduction of 10-12% in fuel consumption (Abele 2009), which is equivalent to reduction of greenhouse gas emissions (CO_2). The main *EE-VERT concept is the electrification of auxiliary systems, operating demand oriented and supplying them, whenever possible, with recovered brake and CO2-neutral energy* (Ward et al 2008, Abele 2009). Besides the electrification of auxiliaries, the central concept of EE-VERT introduces an overall energy management strategy for optimization of electricity generation, storage and usage elements (Abele 2009).
This paper shows in the following sections, which simulations have been carried out in order to support auxiliary component development including their optimization and control, before they are finally integrated into a demonstrator vehicle. In order to exemplify the *process steps in simulation supporting overall development***,** the engine cooling water pump is taken all along this paper.

DEVELOPMENT SETUP

The partners that compose the EE-VERT consortium have different specialization fields. Thus they all have different development processes. But on the other hand, all partners pursue the same project objective, which is to improve the overall vehicle efficiency and to reduce fuel consumption. The improvement activities have been defined in the project proposal. The different partners are developing component prototypes and together with these prototypes simulation models are being generated for testing. Based on these models, first system integration is done in simulation followed later by integration tests on a test bench. Finally an improved prototype (this is the demonstrator vehicle) is built in order to show that the project objectives are met. The

[1] EU-Funded Project "EE-VERT – Energy Efficient Vehicles for Road Transportation", www.ee-vert.net
Members of the consortium are MIRA Limited (UK), Volvo Technology AB (SE), Centro Ricerche Fiat S.C.p.A. (IT), Robert Bosch GmbH (DE), Lear Corporation Holding Spain SL (ES), Engineering Center Steyr GmbH & Co KG (AT), FH JOANNEUM Gesellschaft mbH (AT), Universitatea Politehnica din Timisoara (RO) and S.C. Beespeed Automatizari S.R.L. (RO).

tailored overall development process setup for EE-VERT is depicted in Figure 1 and shows that simulation accompanies development along the project from requirements specification until final system demonstration.

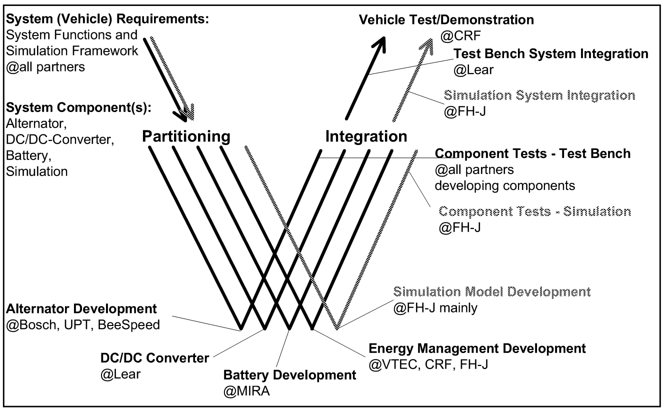


Figure 1: Tailored Development Process Model (V-Model) for the EE-VERT Project and its Consortium.

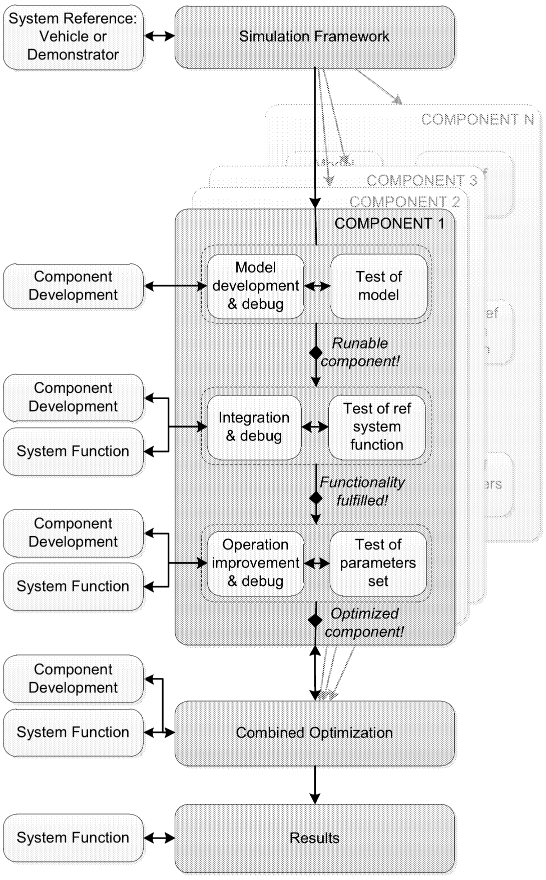


Figure 2 Process Steps in Simulation Supporting Overall Development

Figure 2 depicts the steps taken in simulation in order to provide development support in more detail. This includes the interfaces to concurrently running activities in physical component development.

The first step is to establish a ***simulation framework***, which has to fulfil two main tasks:

(1) The simulation framework has to establish a reference. Thus a reference simulation for an Alpha Romeo 159 jtdm has been implemented. This is the vehicle, which the auxiliary electrification concept is finally applied to.

(2) The simulation framework has to be flexible enough to enable easy integration of various different component models and optimization concepts. Thus the simulation is setup in a modular and configurable way, which now allows single parameters, modules or even whole optimisation concepts in various combinations to be switched on or off.

Simulation framework development is followed by component development, which is organized in (component) ***model development***, (component model) ***integration*** and (component model) ***operation improvement*** all of them interfacing physical component development and the later also system function development. This holds also for ***combined optimization***, which bothers on top of the components (models) for further system function optimization as e.g. overall energy consumption. Final ***results*** are simulation results which show a system function improvement according to the defined reference.

In the following sections the single simulation steps supporting physical component and system function development are explained in detail along the example of optimizing energy consumption by the combustion engine cooling circuit.

SIMULATION FRAMEWORK

The simulation framework is called ***EAMST*** and is an *Energy Analysis and Management Simulation Tool* (Mathis et al. 2012) which has been developed within EE-VERT and is implemented in the Matlab/Simulink® environment. Figure 3 shows the EAMST overall structure.

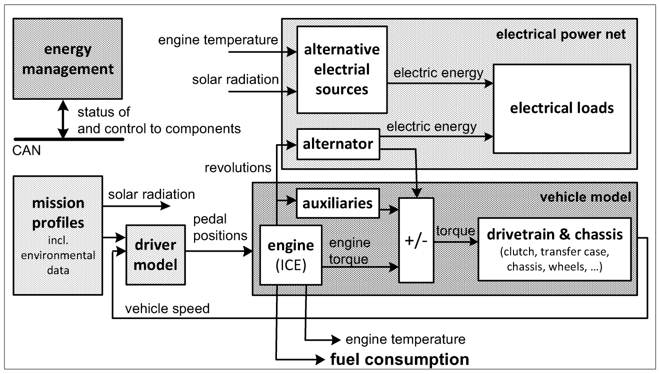


Figure 3: Simulation Framework Structure

The simulation is set up in a cause-effect or forward approach which allows application of online control and management strategies. The main simulation tool components are a vehicle model, and a driver model giving input to the vehicle by following mission profiles. The vehicle model in turn consists of an Internal Combustion Engine (ICE) with the drivetrain and chassis model as a main load attached to it. Further loads to the ICE are auxiliary systems which the alternator is also a part of. The electric power net (e-net) in turn is a load to the alternator.

Additionally attached alternative power sources provide their energy directly to the e-net with no feedback to the ICE.

On top of the component systems energy management is run, optimizing overall electric power consumption including generation, storage and usage. Consequently, the main function of the vehicle model in this simulation is the evaluation of fuel consumption and, consequently, CO2 emissions.

Precondition to the electrification of auxiliaries is an efficient power generation. For this purpose ***a dual power net capable to recover brake energy*** has been introduced and is shown in Figure 4.

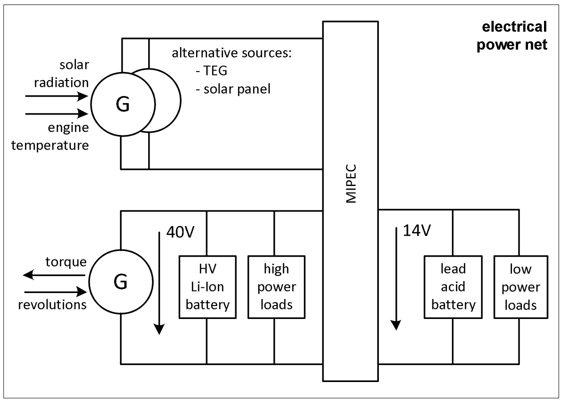


Figure 4: Dual Power Net as a Basis for the Electrification of Auxiliaries

At a higher voltage level electrical energy can by generated more efficiently. Thus in this approach an improved 40V alternator is used for power generation. In combination with a 40V Li-Ion battery recuperated brake energy can be buffered on the high voltage side, as a conventional 14V lead acid battery is not capable of absorbing and storing peak brake energy pulses of up to 8-10kW. Low voltage consumers are feed via a Multiple Input Power Electronic Converter (MIPEC) with 14V power.

Alternative energy sources are directly fed via the MIPEC to the low power net. Apart from the AC compressor, which is a high power load, ***electrified auxiliaries*** are situated on the low power net.

COMPONENT (MODEL) DEVELOPMENT

According to specifications derived from system requirements, the models for the different components were concurrently carried out for all partners involved in the project. Generally auxiliaries are modelled based on characteristics providing their power consumption in the point of operation.

Considering that the mechanically driven water pump of a conventional vehicle is coupled to the engine by a belt and thus it runs at speeds related to engine revolutions. As a result the pump is oversized in order to establish sufficient cooling over the whole operating range. Typically a mechanically driven state-of-the-art water pump has an efficiency of about 40%. EE-VERT proposes an electrically driven water pump (EWP), which is able to accurately adjust the actual cooling demand of the internal combustion engine. A volume flow rate higher than 40l/min is not needed. Therefore the power demand does not exceed 400W.

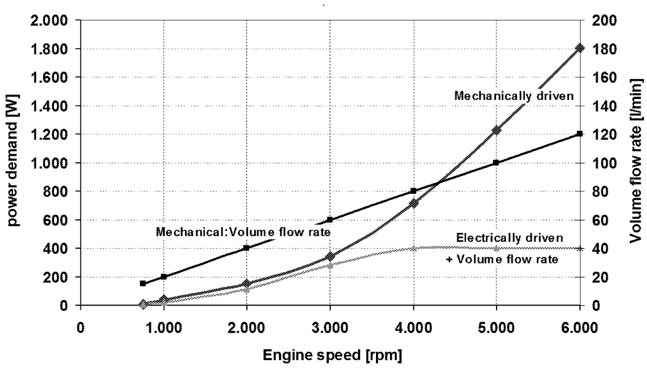


Figure 5: Water pumps characteristics

Based on the electrical water pump characteristics, a model was carried out. *During the model development process the obtained standalone results are double-checked with the partner responsible for physical component development.* At the end of this step, a runnable component model is proven and is ready for being integrated into the simulation framework.

MODEL INTEGRATION

Mechanically driven auxiliary systems are inherently considered in the engine power characteristics as they are attached as loads to the ICE. For electrification the mechanical components have to be removed from the engine. As in simulation the mechanical auxiliaries cannot be removed from the engine power efficiency map, this is carried out by adding mechanical auxiliary models acting as a source which increases the available torque to loads. The new electrical auxiliaries are added as a load to the e-net (see Figure 6).

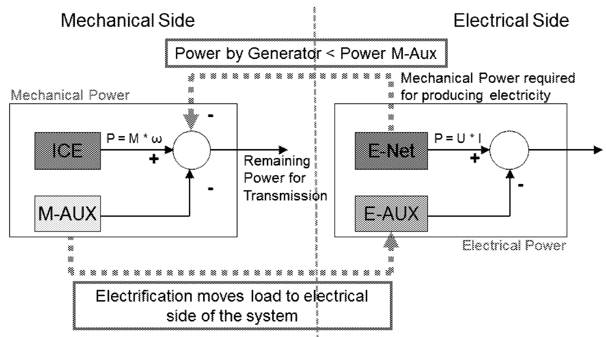


Figure 6: Concept of electrification of auxiliaries

Following up the water pump example, Figure 7 shows the cooling system used in simulation to operate the pump. The ICE temperature results by evaluating the thermal balance of intake air, fuel value, emission gas heat content as well as incoming and outgoing cooling water heat energy. As an effect the engine warms up or cools down. The cooling water is cooled by the radiator. The engine fan and the operating speed of the pump establish the required overall heat removal.

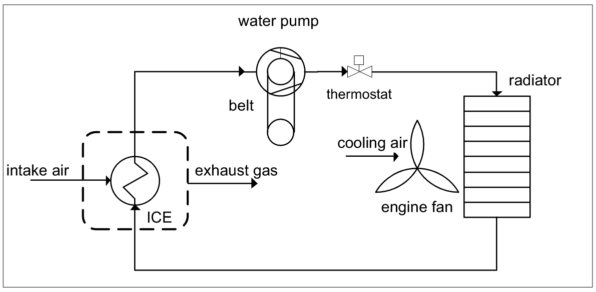


Figure 7: Cooling Circuit for a Mechanical Driven Water Pump

For testing both mechanical and electrical water pump a simulated test-bench environment was prepared, containing the components depicted above. Together with the car manufacturer, model integration verification was realized using the mechanical component as a reference. Test results show the proper operation of the mechanical water pump, see Figure 8.

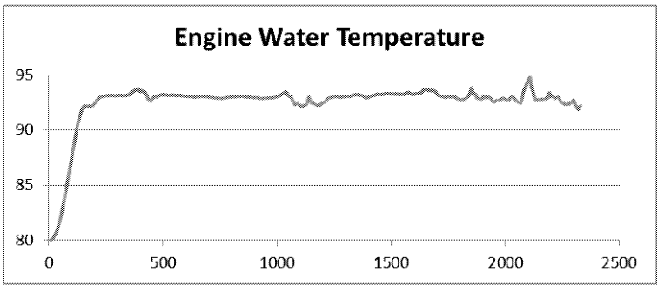


Figure 8: Performance of mechanical water pump during Artemis (home-to-work) driving cycle

OPERATION IMPROVEMENT

The mechanical components used to be adjusted for operating reasonably far from the critical operational point. This implies to have a safety margin for compensating their lack of accuracy and avoid unsafe conditions regardless of consumed energy. Unlike their mechanical counterparts, electrified components can be controlled with a high accuracy. Therefore, it becomes feasible to seek for optimal operational points.

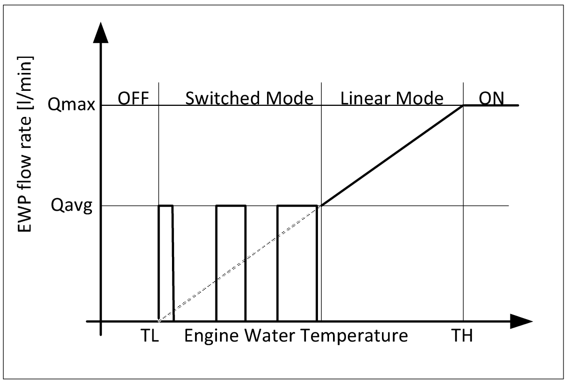


Figure 9: Operation Modes of an Electrical Water Pump

The electrified water pump is smaller sized and driven on demand. Dependent on cooling water temperature this pump is run in one of four modes: (1) off, (2) switched, (3) linear and (4) full speed on.) (see Figure 9).
Modes are introduced in order to run the pump at best in a high efficiency range. For determining such a high efficiency range a set of parameters were experimented.
Some representative results of this phase are shown in Figure 10. Reference Car with state-of-the-art components depicts the benchmark. Case1 and Case2 show the influence of modifying operational range of the water pump in switched mode. Case1 attempts maintaining the pump mass flow between 30 and 40l/min whereas Case2 between 40-50l/min. In Case3 the electrified water pump is operated in linear mode. According to these results Case2 represents the best operational conditions for the electric water pump.

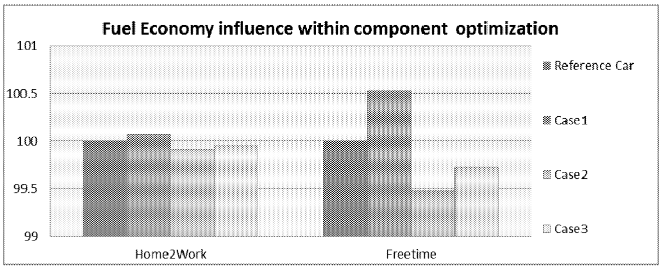


Figure 10: Component optimization of water pump

COMBINED OPTIMIZATION

Up to now each component has been individually developed, integrated and optimized. However, that does not necessarily imply an optimized system function. Thus next step in the *development process* is to analyse the plausibility of combining component functions or even changing the way that the components are used, in order to obtain a coordinated actuation and an improvement at system level.

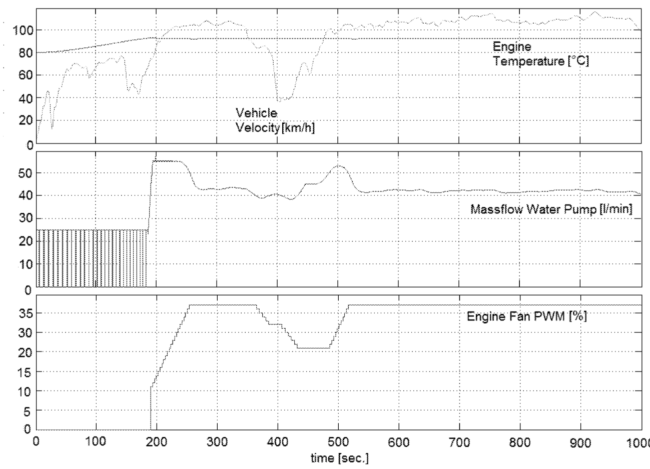


Figure 11: Combined operation of water pump and engine fan (mass flow is control between 40 and 50l/min)

Combined optimization for the engine cooling circuit can be achieved as follows. The engine water temperature is controlled by two different actuators: the water pump and the engine fan. If the operation of these two actuators is not coordinated, instabilities may occur. To avoid that, it is considered that the water pump is the main controller of the water temperature, either in switched mode or in linear mode. On the other hand, the engine fan observes the mass flow of the water pump and gradually varies its speed for maintaining the mass flow within a defined range. As a consequence, the water pump is capable to control a big span of the water temperature with the same mass flow, due to the help provided by the engine fan. This combined optimization is shown in Figure 11.

RESULTS IN SIMULATION

At the end of the *Process Steps in Simulation Supporting Overall Development* the assessment of all the improvements can be done. As a basis for the electrification of the auxiliaries, first the ***dual power net*** has been introduced. This concept introduction results in about 10% in fuel consumption on NEDC. On basis of the dual power net, as a next step combustion engine auxiliaries have been ***electrified and optimized***. This electrification includes water pump, oil pump, vacuum pump, fuel pump and engine fan. Simulation results show that electrification of auxiliaries allows reductions in fuel consumption of up to nearly 20% as shown in Figure 12.

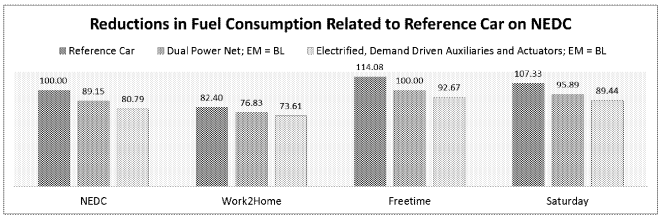


Figure 12: Evaluation on NEDC and real-life driving cycles (Work2Home, Freetime, Saturday).

The basic fuel consumption for the AR159 jtdm on NEDC is 5.9l diesel per 100km. Consequently a reduction in fuel consumption of 1% is equal to 1.57g CO_2/km (1l diesel leads to 26.6g CO2/km). 0.07l diesel per 100km is necessary to generate an electrical power of 100W. The basic electrical power net load was assumed to be 350W on real-life and NEDC.

CONCLUSION AND OUTLOOK

Within the EE-VERT project, in parallel to concept evaluations in simulation, improved electric auxiliary components are developed. The Process Steps in Simulation Supporting Overall Development, reported in this paper, represents a successful deployment of concurrent engineering.

In view of the project EE-VERT (Simpkin et al. 2012), it can be stated that electrification and optimisation of engine auxiliaries contributes a part nearly as big as the overall EE-VERT target of 10-12% in reduction of fuel consumption. Thus a main further step in EE-VERT is to set up a demonstrator vehicle which incorporates this improvement concept of electrified and optimized auxiliaries for final concept proof.

REFERENCES

European Environment Agency. 2008. “Greenhouse gas emission trends and projections in Europe 2008” *EEA Report No 5*.

Ward, D. , M. Granström, A. Ferré. 2009. “Energy Efficient Vehicles for Road Transport — EE-VERT” *Advanced Microsystems for Automotive Applications 2009*, VDI-Buch, part 1, 3-11, DOI: 10.1007/978-3-642-00745-3_1

Abele, M. 2009. “Reduction of fuel consumption in conventional vehicles by electrification of auxiliaries” *21th Int. AVL Conference Engine & Environment*, Sept. 10th-11th, Graz

Simpkin, R. et al. 2012. “Energy Efficient Vehicles for Road Transport” *Transport Research Arena (TRA 2012)*, April 23rd - 26th, Athens, to be published

Mathis C., G. Knoll, R.Estrada Vazquez, A. Steinhuber, EE-VERT Consortium. 2012. “Advanced Energy Analysis and Management Simulation for Low-Emission Conventional Vehicles” *6th Forschungsforum der österreichischen Fachhochschulen*, April 11th-12th, Graz, to be published

AUTHOR BIOGRAPHIES

CLAUDIA MATHIS was born in Höchst, Austria and went to Technical University of Graz, where she studied Telematics and received her Master’s Degree in 1996. This was followed by a PhD in Computer Science in 2000 also from the Technical University of Graz. Thereafter she worked for 9 years as software engineer in the fields aviation, finance, medical and latest automotive. During this professional period she had responsibility for software quality management (ISO9000) and software process improvement (ISO 15504), requirements management, project management, safety related to software according to the IEC 61508, team and department management. In 2009 she joined the University of Applied Sciences, Fachhochschule JOANNEUM (site Kapfenberg), as a senior teaching staff member.

ALFRED STEINHUBER was born in Leoben Austria. He went to the University of Applied Science FH JOANNEUM, Kapfenberg, where he received his diploma degree in Electronics Engineering in 2009. This is followed by a Master’s program in Advanced Electronic Engineering, also FH JOANNEUM, he is currently in. Besides his studies he started his professional carrier at MAGNA STEYR, Graz in the field of model based function development with focus on electrical and thermal energy management for Hybrid Vehicles. Since 2009 he continues these activities at FH JOANNEUM in view of new vehicle concepts.

RAUL ESTRADA VAZQUEZ was born in Alvarado, Mexico and received his BSc in Electronics at Veracruz Institute of Technology in 1998. From 1998 to 1999 he worked for Laguna Verde Nuclear Power Station. Working as a Teaching Assistant at Monterrey Tech he received his MSc in Automation in 2002 and continued teaching there until 2006. In 2006 he joined ADEX S.L., in Madrid, Spain, working as a leader in project of optimized control. Since June 2009, he is researcher in fields of simulation and energy management strategies for new vehicles at FH JOANNEUM.

QUALITY ASSURANCE

A VALIDATION OF PACE RATING USING VIDEO TECHNOLOGY

Peeradaech Suwittayaruk
Dirk Van Goubergen
Ghent University
Technologiepark 903
B-9052 Ghent-Zwijnaarde, Belgium
E-mail: peeradaech.suwittayaruk@ugent.be,
dirk@vangoubergen.com

KEYWORDS
Pace rating, video technology, reference video, actual video, validation

ABSTRACT

In direct time study, pace rating is an important element to determine time standards. In the literature, pace rating has always been recognized as being challenging and subjective. Recently, a tool that can compare the tempo of work motions on (real-life) actual videos with the tempo of work motions on a calibrated reference video, showing decision making patterns on pace rating has been developed to improve pace rating practice. Although this approach is interesting, there has been little discussion on validating the new proposed way. In practice, ratings with errors within ± 5% are considered excellent while those with errors within ± 10% are not excellent but good. In this paper, based on descriptive and inferential statistics obtained from experiments, we show that it is very challenging to reach these error levels when rating actual videos containing complex motions.

INTRODUCTION

In manufacturing and service organizations it is necessary to have accurate and precise time standards for all tasks in order to provide qualitative input for designing, executing and managing operational activities. The time required to produce a product at a workstation is determined through work measurement techniques of which direct time study is the most widely spread technique (Barnes 1980). An essential part of this technique for determining a standard time is rating the pace of the observed work activities. Hence, the mean observed time for each element being performed can be normalized in order to become normal reference time applicable to every worker (called 'normal time').

The quality of the standard time is considerably dependant on the quality of the pace rating process. Niebel and Freivalds (2003) show the relationship between the observed time, the rated pace, and the normal time. A rating higher than a standard performance will be assigned to an observed time that is less than the normal time. On the contrary, when the observed time is greater than the normal time, it will be rated as below the standard performance. Since the beginning of the previous century, pace rating has been common knowledge that it has always been considered as difficult, subjective, challenging and even controversial (Barnes 1980; Miller and Schmidt 1990; Kanawaty 1992; Meyers and stewart 2002; Niebel and Freivalds 2003; Groover 2007).

Pace rating has always been one of the main responsibilities for industrial engineers (IEs) or time study persons responsible for setting time standards. To evaluate work rates, in the traditional way, IEs or time study persons are trained to remember a speed of work motions at 100% standard pace such as dealing 52 cards into four equal stacks in 0.5 min. To perform pace rating, the IE sees a worker performing a task at a workstation. Then an information processing step happens in the brain where the actual work rate is compared with is remembered as the 100% standard. Finally, the rated pace is evaluated and documented.

To improve pace rating practice, Van Goubergen and Vancauwenberghe (2006) proposed an interesting idea of pace rating based on video technology. Work motions on a calibrated reference video and an (real-life) actual video filmed are shown at the same time on a screen. By adjusting the speed of the reference video, IEs or time study persons can synchronize the work motions in both videos and thus quantify the work motions on the actual video being studied.

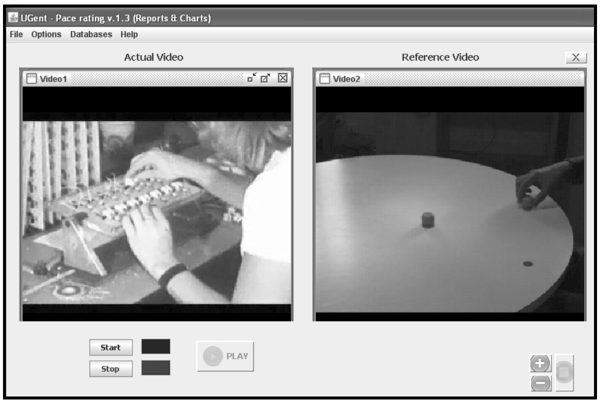


Figure 1: A pace rating software

Based on concepts of discrete-event dynamic systems, Suwittayaruk and Van Goubergen (2011a) have extended the idea of synchronizing the work motions on reference and actual videos by developing a new software (Figure 1) that can visualize response selection and execution by showing decision making patterns and help IEs or time study people to improve pace rating practice and serve as an aid to communicate between management and union as illustrated in Figure 2.

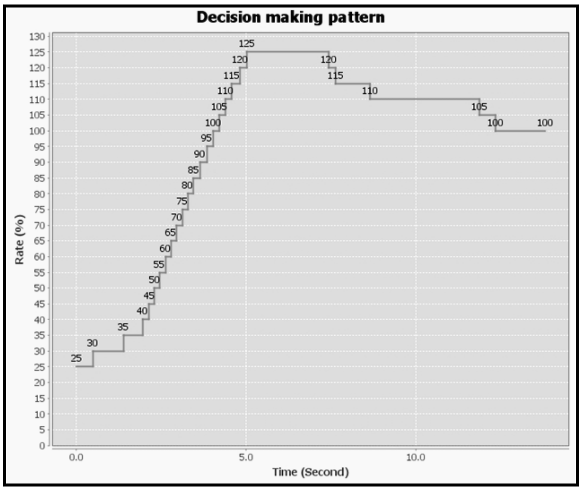


Figure 2: A decision making pattern

As a rule, in practice, ratings with errors within ± 5% are considered excellent while those with errors within ± 10% are not excellent but good (Meyers and Stewart 2002). To the best of our knowledge, no one investigated the accuracy of the obtained pace figure. Suwittayaruk and Van Goubergen (2011a) focused on using the final response as the rated pace.

Previous work has only utilized decision making patterns obtained from experiments to assess rating consistency based on sensitivity, specificity and a cut off line calculated by optimizing binary outcomes that are coded in decision making patterns using signal detection theory (Suwittayaruk and Van Goubergen 2011b).

To extend the body of knowledge, the aim of the research described in this paper is to validate rating accuracy of pace rating using video technology with regard to the framework of the criteria. Our method of the validation of rating accuracy is largely based on four zones : the green zone (error ≤ ± 5 %), the yellow zone (± 5 % < error ≤ ± 10 %), the red zone (± 10 % < error ≤ ± 15 %) and the black zone (error > ± 15 %). In this study, we believed that when rating work motions on actual videos containing complex motions, it is extremely difficult and challenging to reach the green or yellow zone**.**

METHODS

Participants

Participants in this study included 20 graduate Industrial Engineering and Operations Research students at Ghent University, Belgium. They had backgrounds in pace rating (the traditional way) taught in a six-credit work measurement and method engineering course.

Apparatus

Pace rating software

The software package (Figure 1) developed at the Department of Industrial Management, Ghent University, Belgium was used to conduct the experiments.

The reference video

The reference video used in the experiment, showing a very easy motion pattern, was analyzed with MTM-1 and normalized at 100% pace by the authors using Ulead VideoStudio version 9 as displayed in Figure 3. The video contains motions such as reaching, (easy) grasping, moving, positioning, and releasing movements with the same distance. MTM-1 is a predetermined time standards technique that provides the highest accuracy compared to other similar systems and gives a normal time based on predetermined time values at pace 100% (Antis *et al.* 1973).

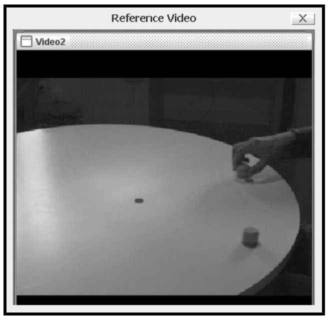


Figure 3: The reference video

Actual videos

Five actual videos were chosen from two different sources to conduct the experiments:

1. The actual video 1 (Figure 4) showing a very easy motion pattern was analyzed and developed with MTM-1 by the authors using Ulead VideoStudio version 9. This video consists of motions over the same distance as the reference video.

Figure 4: The actual video 1

2. The actual video 2 (Figure 5) showing an easy motion pattern was analyzed and developed with MTM-1 by the authors using Ulead VideoStudio version 9. Like the reference video, the second video also contains reaching, (easy) grasping, moving, positioning, and releasing, but movement distances are completely different**.**

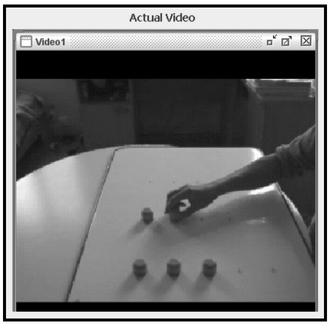


Figure 5: The actual video 2

3. The set of actual videos 3, 4, and 5 comprises three videos showing hand movements with complex motion patterns rated at 100% pace using the traditional method by averaging the group opinion of a control group of over two hundred practicing IEs on each scene pictured. These videos were selected from the TMI pace rating video collection (Watmough 1975): turn and point flap-shirts(Figure 6), heat-seal a part in a bag(Figure 7) and bar-tack sanitary belts (Figure 8).

Figure 6: The actual video 3

Figure 7: The actual video 4

Figure 8: The actual video 5

Experimental procedure

To conduct the experiment, the following instructions were given to participants. Work motions on both videos were shown simultaneously without giving any quantitative information on the pace. The participants were asked to compare the two videos with regard to pace of working as they would visually perceive this. As the starting point the tempo of work motions of the reference video under study is always shown at a lower pace (at 20%). When the tempo of the work motions on the reference videos is perceived by the participant as being lower or equal than the tempo of the work motions on the actual video (at these points, the participant needs to say “Up”), the plus button needs to be clicked by an author. This causes the tempo of work motions of the reference video to increase. Then, the same question is asked repeatedly until the tempo of the work motions on the reference videos is judged as being higher (at the last point, the participant needs to say “Stop”). Finally, the stop button needs to be pushed by an author in order to end the experiment. Each click made while conducting the experiments, along with the corresponding processing time, is recoded in the database and then decision making patterns are generated.

Data analysis

Independent variable

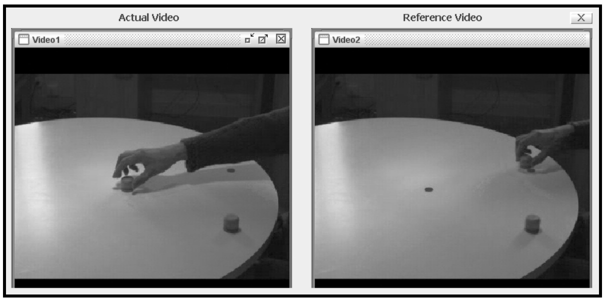


Figure 9: Set 1 showing the very easy pattern (the right side) versus the very easy pattern (the left side)

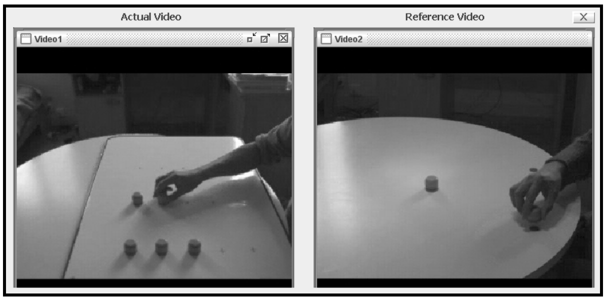


Figure 10: Set 2 showing the very easy pattern (the right side) versus the easy pattern (the left side)

The set consisting of a reference video and an actual video was defined as the independent variable considered in this investigation. The independent variable was divided into five sets:

1. The very easy pattern versus the very easy pattern (Figure 9).

2. The very easy pattern versus the easy pattern (Figure 10).
3. The very easy pattern versus complex pattern 1 (Figure 11).
4. The very easy pattern versus complex pattern 2 (Figure 12).
5. The very easy pattern versus complex pattern 3 (Figure 13).

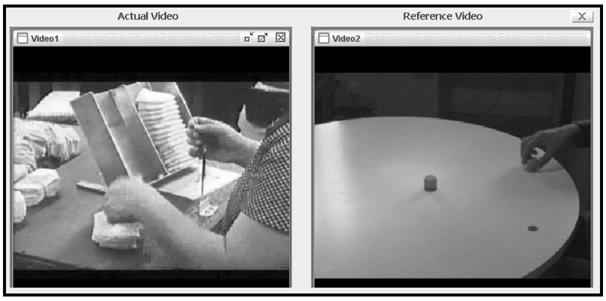


Figure 11: Set 3 showing the very easy pattern (the right side) versus complex pattern 1 (the left side)

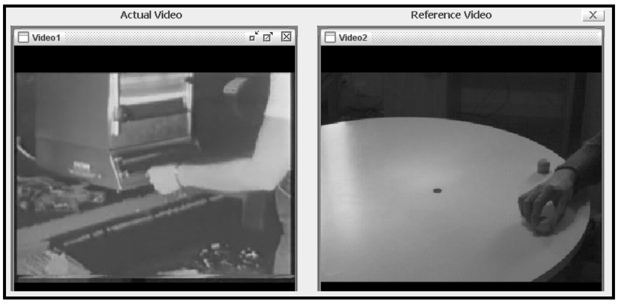


Figure 12: Set 4 showing the very easy pattern (the right side) versus complex pattern 2 (the left side)

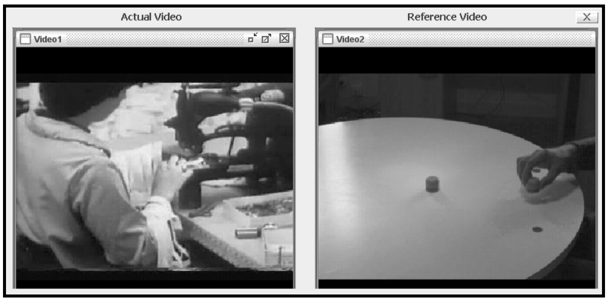


Figure 13: Set 5 showing the very easy pattern (the right side) versus complex pattern 3 (the left side)

Dependent variable

Rating accuracy was selected as the dependent variable. Accuracy refers to the proportion of responses which are true or correct, expressed as an average percentage error.

Measurement

One hundred decision making patterns (20 for each set) were collected as data. Figure 14 shows an example of a pattern obtained as an output of an experiment. This graph depicts the evolution of the perceived pace as a function of time, showing the outcome of information processing of the pace rating of a participant. In this study, however, we used only the value before reaching the end result as the rated pace to investigate the rating accuracy. In this example, we take 105% as the rated pace.

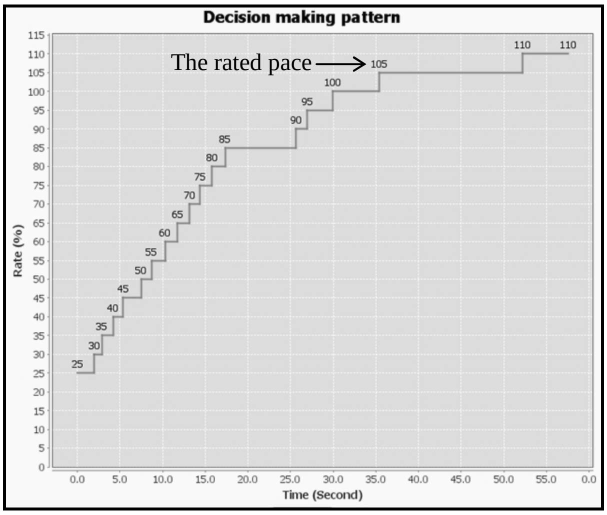


Figure 14: A decision making pattern as an output

Statistical analyses

- Descriptive statistics

In practice, according to Meyers and Stewart (2002), ratings with errors within ± 5% are considered excellent while those with errors within ± 10% are not excellent but good. Each error ($\%e_i$) obtained from experiments is computed by Equation (1) below.

$$\%e_i = \frac{\text{rated pace} - \text{real pace*}}{\text{real pace*}} \times 100 \qquad (1)$$

*Calculated based on MTM-1 or provided together with TMI pace rating video collection.

To assess rating accuracy, four zones were defined as follows:
1. Green zone (error ≤ ± 5 %)
2. Yellow zone (± 5 % < error ≤ ± 10 %)
3. Red zone (± 10 % < error ≤ ± 15 %)
4. Black zone (error > ± 15 %)

Based on tests for normality, the assumptions were not validated. In order to analyze the results, as an alternative, median and range of data of each set were used and displayed as descriptive statistics.

- Inferential statistics

As mentioned above, the assumptions were not validated. Median of each set was used as data to investigate the difference levels of rating accuracy. Wilcoxon signed-rank test was performed to test the hypotheses for each set of experiments. The null and alternative hypotheses tested in this investigation consisted of three sets.

1. H_o: Median of the errors in each set is equal or less than ± 5 %.
   H_a: Median of the errors in each set is more than ± 5 %.

2. H_o: Median of the errors in each set is equal or less than ± 10 %.
H_a: Median of the errors in each set is more than ± 10 %.
3. H_o: Median of the errors in each set is equal or less than ±15 %.
H_a: Median of the errors in each set is more than ± 15 %.

Statistical significance was analyzed through the use of Minitab version 13.2. The results of hypothesis testing were considered statistically significant when $p < 0.05$.

RESULTS AND DISCUSSIONS

Descriptive statistics

Figure 15 displays descriptive information of the percentage rating error of all test subjects in each set. Figure 15 shows that set 1 has the most error values (80%) inside the green zone. For sets 2 and 3 some errors (but less) are also in the green zone but some errors appear in the black zone. Sets 4 and 5 showed much less error values inside the ±5% zone. Interestingly, the results obtained for sets 4 and 5 show approximately 60 % of data points in the black zone.

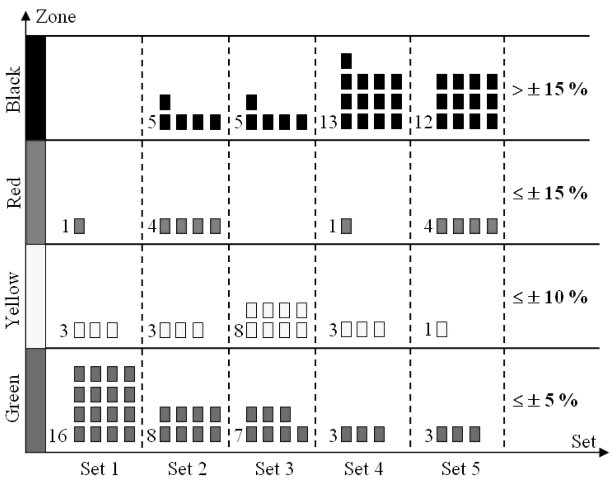


Figure 15: Errors of each set in four zones

As the assumptions of testing for normality were not validated, median of each set was used as data. The bars and vertical lines in Figure 16 depict the medians and ranges of the error data in each set.

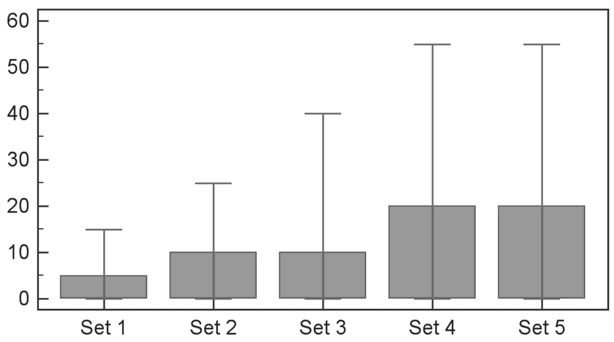


Figure 16: Median and range of data of each set

Comparing the results, one can see that set 1 gives both the smallest median error (5%) as well as the smallest range of error, while sets 4 and 5 have the highest median errors (20%) and widest range of errors. Sets 2 and 3 show intermediate median errors (10%), however set 3 has a wider range of error than set 2.

As descriptive data displayed in Figures 15 and 16 demonstrate different values of the rating error of each set, the results seem to indicate that set 1 (which has an vary easy motion pattern) has lower values than the other sets showing more complex motion patterns This is of course not a sound statistical conclusion. We used Wilcoxon signed-rank test to obtain more evidence as described in next section.

Inferential statistics

We used inferential statistics to test our hypotheses. Compared with the level of significance (0.05), the p-values of each set obtained from each hypothesis that were first detected as no significant differences were used as data.

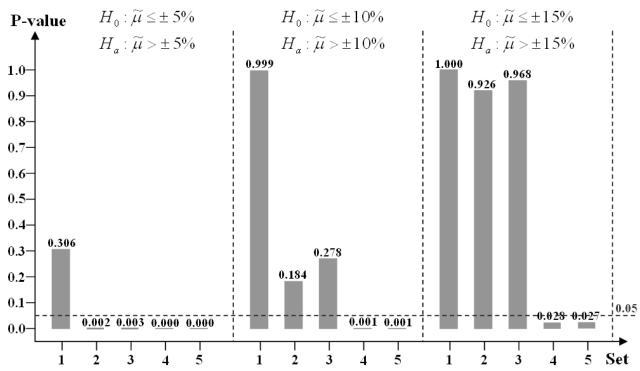


Figure 17: P-values obtained from Wilcoxon signed-rank test

As stated in the Introduction and Methods sections, according to Meyers and Stewart (2002), rating errors within ±5% are excellent. As can be seen in Figure 17, only set 1 has a p-value > 0.05 in the first test (H_o: $\tilde{\mu} \leq$ ±5%; H_a: $\tilde{\mu}$ >±5%). Rating errors within ±10% are considered as good. The second test (H_o: $\tilde{\mu}$ ≤±10%; H_a: $\tilde{\mu}$ >±10%) shows that sets 2 and 3 have a good result. Sets 4 and 5 were not detected in any of the three tests. This means that only the rating of set 1 (rating with the very easy motion pattern) is inside the ±5% range, while sets 2 and 3 are within the ±10% range. Errors obtained from ratings on the sets 4 and 5 are outside the ± 15% range.

CONCLUSIONS AND FURTHER RESEARCH

As expected, for rating work motions on actual videos containing complex motions it is extremely difficult and challenging to reach ± 5% zone or even ± 10% zone**.** Our data clearly shows that rating on more complex motion patterns gives higher errors than when very easy or easy patterns are evaluated. This may mean that, when rating pace based on video technology is used in practice, obtaining the real pace when rating is not obvious when complex motion patterns are involved. However, our work does show points for further research: For example, the complex motion pattern of set 3 gives better accuracy than other complex motion patterns (sets 4 and 5). An index of difficulty may need to be considered and defined. The present study has only examined rating accuracy. But, rating precision will need to be taken into account too. Based on descriptive statistics as displayed in Figures 15 and 16, the results seem likely that rating on the very easy or easy motion patterns gives higher precision than rating on more complex motion patterns. As a next step in our research, we are currently in the process of investigating how to improve accuracy as well as precision and finding out other ways to improve pace rating practice using video technology.

REFFERENCES

Aft, L. S. 2000. *Work Measurement and Methods Improvement*. John Wiley and Sons, Inc New York.

Antis *et al.* 1973. *The basic motions of MTM(4th ed.)*. The Maynard Foundation, Florida.

Barnes, R. M. 1980. *Motion and Time Study Design and Measurement of Work (7th ed.)*. John Wiley and Sons, Inc, New York.

Groove, M. P. 2007. *Work Systems and the Methods, Measurement, and Management of work*. Pearson Prentice Hall, Inc, New Jersey.

Kanawaty, G. 1992. *Introduction to Work Study (4th ed.)*. International Labor office, Geneva.

Meyers, F. E. and Stewart, J. R. 2002. *Motion and Time Study for Lean Manufacturing (3rd ed.)*. Prentice Hall, Inc, New Jersey.

Miller, D. M. and Schmidt, J. W. 1990. *Industrial Engineering and Operations Research*. John Wiley and Sons, Inc, Singapore.

Niebel, B. and Freivalds, A. 2003. *Methods standard and work design (11th ed.)*. McGraw-hill, Inc, Boston.

Suwittayaruk, P. and Van Goubergen, D. 2011a. *A tool to visualize response selection and execution on pace rating.* 9th Annual Industrial Simulation Conference,Venice, Italy, 26-30.

Suwittayaruk, P. and Van Goubergen, D. 2011b. *Investigating the perfect separation on binary outcomes coded in decision making patterns for pace rating.* 25th Annual European Simulation and Modelling Conference, Guimaraes, Portugal, 145-149.

Van Goubergen. D. and Vancauwenberghe, F. 2006. *4 Mudas of Productivity : Quantifying waste in Work Methods*. IIE Annual Conference, Florida.

Watmough, E. B. 1975. *TMI Pace Rating Videos*, Tempo Manufacturing Institute.

BIOGRAPHIES

PEERADAECH SUWITTAYARUK is a PhD student in Industrial Engineering and Operations Research at the department of Industrial Management, Ghent University (Belgium). His research interests lie in work measurement and motion study, ergonomics and lean manufacturing. In his PhD he is researching on improving work measurement practice for method improvement and process design using video technology.

DIRK VAN GOUBERGEN is a professor at the department of Industrial Management at Ghent University. He is an expert in the area of work measurement and method engineering, productivity improvement and lean manufacturing. Additionally, he has more than fifteen years of international experience as a trainer/consultant in the area of lean manufacturing within different industrials throughout Europe. He has a M.S. degree in Mechanical Engineering from the Royal Military Academy (Brussels-Belgium), a M.S. in Industrial Management from Ghent University and a PhD in Industrial Engineering from Ghent University. He is a senior member of the Institute of Industrial Engineering(IIE).

SEMANTIC TECHNOLOGIES AND AUGMENTED REALITY FOR INSPECTION AND MAINTENANCE PROCESSES

Janek Götze1, Egon Müller1, Andreas Rutsch1,2, Christian-Andreas Schumann2
1 Chemnitz University of Technology
Institute of Industrial Management and Factory Systems
Chemnitz, Germany
2 West Saxon University of Zwickau
Institute of Management and Information
Dr.-Friedrichs-Ring 2a
D-08056 Zwickau, Germany
E-mail: christian.schumann@fh-zwickau.de

KEYWORDS
Augmented Reality, Semantic Technology, Facility Management.

ABSTRACT

Facility Management includes as main processes inspection and maintenance. Recently, the knowledge of the facility planning procedures are not or only partly available for the operating tasks of the facility management. The approach is directed to a close-loop information and knowledge flow between the main fields of facility management. Therefore, the latest mobile technology is used in order to be able to apply augmented reality for service and support processes. The approach will be related to special methods of knowledge management focused to the semantic network theory and practice. So, the cross-linked information and knowledge flow in the facility management will be provided and based on the highest and efficient level of recent state of the art.

THE ISSUE OF COMPLEXITY IN INSPECTION AND MAINTAINING OF INDUSTRIAL FACILITIES (IF)

Along the life cycle of an industrial plant enormous amounts of data are produced. These are distributed among the various planning and operational phase of the partners involved. (Hänsch and Endig 2010) The form of data includes structured databases on layouts or 3D models as well as unstructured text floating in planning reports. The overall view of all data enables a detailed view of the nature of the target system, but also with respect to the operational phase, the information on the current actual state. Despite the existing data important decisions will be made in many processes only on a relatively small base of information today. It has several causes. Firstly, the data are available in many different non-compatible formats. On the other hand, no central access to all data exists due to the distribution of benefits across multiple partners. Even if both problems would be solved with many decisions, such a large and complex data base would be created that a time-depth consideration of adequate and quality will be excluded. There are no efficient methods for reducing information with regard to their decision to produce these automated and to provide to the user in an appropriate and intuitive manner.

THE BASIC APPROACH FOR SUPPORTING DECISION MAKING IN INSPECTION AND MAINTAINING OF IF

The approach is focused to model, method and process development for a systematic integration of real and virtual worlds. The decision-making processes will base on all available information in the future. The following two scenarios have special practical relevance, since they depend for their meaning for the heat output, efficiency, and not least the safety of current and complete information. The hand-over of the industrial plant to the operator will take place between the planning and operation phase. This has to be decided on the basis of the planning, whether the system is ready for acceptance. After the successful inspection and hand-over of the equipment the continuous maintenance is essential. The decision-making process involves a huge volume of data from planning and operational phase from the scheduling of maintenance orders up to the operational implementation. Both scenarios are characterized by a very complex and heterogeneous data layer, which is dispersed beyond. The desired method to be developed with the tools and technologies will help decrease the operator and maintenance processes carried out on the basis of current information. It could be safer and more economical. For this purpose, the following identified basic requirements are prepared. The user receives an understandable visual target-comparison, which clarifies that the real perception coincides with the planned virtual model. It is a systematic integration of information about objects in the virtual world to objects in the real world. The amount of available information is automatically reduced to a bundle of adequate decision-relevant information. The representation of the information held on site and will not impede the work flow. The core technological developments are at first Semantic Technologies for networking of distributed knowledge system and secondly Augmented Reality for visual connection between virtual and real worlds.

THE TECHNOLOGY-DRIVEN PROBLEM SOLUTION APPROACH BY R&D

The representations of the motivation for the research issue show that the overcoming of media clashes with the result of loss of knowledge from the planning phase up to the operational phase of a plant demand the development of a new technological approach for both planning periods.

Moreover, solutions for overcoming media breaks are also developed during the operational phase. These ensure that existing knowledge about plants for maintenance is not or only very inconvenient available. Furthermore, in the future a usable feedback from the operational phase in subsequent planning phases for the purposes of an active knowledge management will be very important. The research group intends the above shortcomings, the consistent use, adaptation and development of advanced technologies to overcome. There are two technological innovations in the focus of the planned R & D project:
Firstly, the development of a technological process for mobile context-based information delivery
Secondly, the development of a reference system for semantic networks to existing knowledge.

Issue 1: The Mobile Context-Based Information Provision

The new development is dedicated to the target making available the existing planning and operational systems knowledge in an intuitive manner. The bases are the commercially available smart phones and tablet PC. Here, the approach goes far beyond a simple mobile access to information systems by means of a Smartphone. The vision is to create a virtual map of a dynamic industrial property. The elements of this model (3d layout, 3D models of plants) occur mandatory in the planning phase of the production system. Therefore, they will be used for another period, after the planning phase. The map includes not only static 3D models. Each of the relevant maintenance objects (system, component) contains all during the planning phase and operation phase identifiable information. The real objects are transformed into a link, where the solutions are discharged from the development focus "semantically linked" to. The resulting knowledge management for production planning provides both knowledge (e.g., maintenance requirements) and operational data (such as port services). The plant maintenance engineer can use the new tool to navigate within the map, retrieve information relevant to maintenance, are incurred through workflow and document tasks. At first, the user is positioned on the map. This is done via optical encodings available in a grid. The codes fulfil two functions. Firstly, the user identifies the area in which it resides. The phone loads the corresponding components of the environment model. On the other hand, distance and perspective will be evaluated on the encoding. This closes the exact position and angle of the user. The decisive parameter is now the degree of matching of the actual, real world with the calculated position and perspective on the system side. The Augmented Reality (AR) technology allows the position and perspective correct projection of the maintenance-relevant information (see Figure 1) on the system by the real camera image of the Smartphone is overlaid with a projection. (Götze et al. 2011) This software ergonomics and user acceptance improved because eliminates tedious navigation through menu structures.

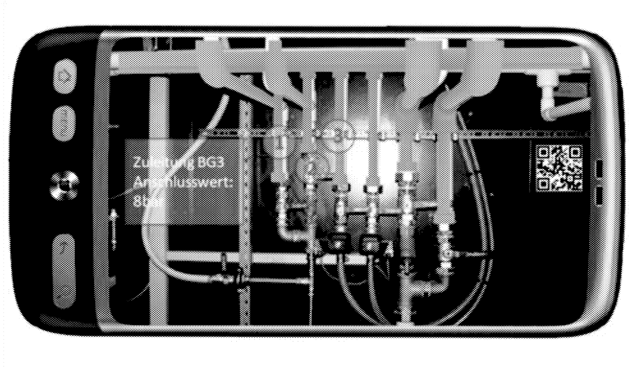


Figure 1: Example of AR Support in the Maintenance

Another important aspect to improve the user acceptance is the absence of the need for constant visual contact with an optical marker to keep. Basically, the position and perspective of the Smartphone for loss of label would be lost from the camera field. By developing a model of movement and perspective changes relative movements in the vicinity of the AR model without loss of functionality are possible. The approaches and technological challenges to its implementation are discussed in the description of the work packages.

Issue 2: Semantic network of existing knowledge

The precondition for creating and developing a knowledge cluster is to find out the quality and quantity of the knowledge in the network. Special methods such as different kinds of mapping are available to acquire the needed information and to represent it in the right manner. The opportunities of the knowledge development in networks can be defined on the basis of these analyses. Especially, the level of the knowledge of the network associates and the opportunities of the mutual supplementation of their knowledge are essential for the decision of forming the knowledge clusters in separate partner as well as for the cross-linking of clusters in the framework of a superior knowledge network or a master cluster. After decomposition of the knowledge from a modular-design system into the granulated-design system the description of the relations of the granulated knowledge is very important. Therefore the ontology approach is used. Ontology is typically a (hierarchical) structure containing all the relevant entities and their relationships and rules within a domain. Ontology is related to semantic networks. The semantic network is defined as formal model of terms und its relations. It is used for presenting of knowledge within so called knowledge networks. A semantic network is characterized by a generalized graph. The nodes of the graph are the terms; the edges of the graph represent the relations. Which kinds of relation are allowed is to be defined within the different network models. As a consequence the decomposition diagrams can be transformed into semantic network models.

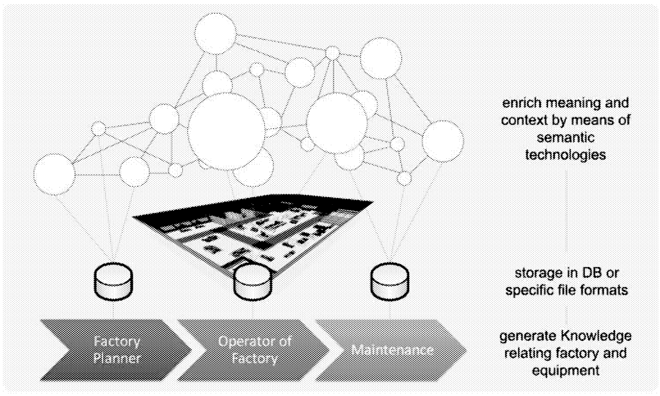


Figure 2: Semantic Networks for the Information and Knowledge Management of IF

THE PROCESSES FROM THE CONCEPTUAL PLANNING TO THE IMPLEMENTATION OF THE PROTOTYPE

The work is done in the framework of a phase model by five steps.

Step 1: Development of a Total Concept of Planning the Knowledge Network

What knowledge is relevant from the perspective of maintenance, and how is it used?

The overall planning concept includes the task to identify the results from different sub-disciplines of the planning construction industry (production system, building services, and maintenance) for the operational maintenance management. It will be restructured and transformed afterwards. This section gives the unused planning outcomes of the project (e.g. production or layout diagrams of various industrial drilling mind works) a new perspective. The results become assignable from the perspective of maintenance. At first, an information demand analysis from the perspective of maintenance management (information seekers) is done for narrowing the focus and the preparation of the information.

Step 2: Development of a Model for Semantic Description of a Uniform, Standardized Form for an Industrial Facility

How to describe the knowledge, so that it will be understood by information systems?

The overall objective of the focal point is the overcoming of knowledge breaks along the life cycle of an industrial estate. This exists on the one hand between these planning disciplines, between the planning phase and operation phase, and on the other hand during the operational phase in the provision of information for operational maintenance. Overcoming these fractures requires knowledge of the realization of a continuous accumulation of plant knowledge. After identification and preparation of needed planning results for the maintenance management, the documents are helpful for creating of a common description model for industrial properties. An industrial estate is the highest level of aggregation, consisting of buildings, areas, facilities to the component level. The model description has the objective to make a common vocabulary and common rules for conclusions of the various sub-disciplines of planning available. The important point is the change of the planning systems and tools, planning disciplines. Therefore, it cannot be further used in a familiar way. The semantic links between the threads in the planning sub-disciplines of planning results are rather on a meta level, which included the planning system. To apply the model description the development of a method for the description is necessary. The focal point is reflected in a unique way, the objectives and the actions of the Federal Ministry of Economics and Technology initiated project THESEUS. THESEUS will simplify access to information, data network to new knowledge and create the basis for new services on the Internet. New semantic technologies are being developed with the help of information on their contents analyzed, can be grouped and linked. Information systems can then interpret this information independently and draw logical conclusions according to certain rules. The project has six application areas for semantic knowledge networked platforms. (Theseus 2012) The project provides virtualFM another new application focus in the field of knowledge accumulation during the development of an industrial plant in the context of maintenance management.

Step 3: Development of the Logistic Information Infrastructure

How can we make use of the distributed information systems as an application?

The focal point includes three areas. For the first one, the model description has to be implemented in order to accumulate knowledge continuously in planning and to make it for future maintenance management available. Secondly, an infrastructure development is needed that integrates the distributed systems and make mobile maintenance processes possible. Finally, for the operational data exchange between the roles involved an open data exchange standard have to be defined. This creates for the user the independence from its IT service provider and can promote faster adoption of the system solution.

Step 4: Technological Approach of a Procedure for Mobile Context-Based Information Provision

How will a mobile terminal become a "real" tool for maintenance processes of the future?

This phase of the project deals with the technological development of an intuitive, mobile access to knowledge bases locally. Mobile devices are the crucial link between information supply and demand information. Because of their connectivity are potentially unlimited resources available to them. The simple access to information is still not the adequate support for maintenance processes. The objective for the development should be to show only relevant information without impairing the user in his activity. It takes an intelligent reduction of the information offer a crucial role. A reduction is necessary because the supply exceeds the amount of information to be processed.

Too much information would lead to "information overload". This effect has not only reduced the effect of new information, but also reduces the amount of processed information. (Hwang 1999) Additional, a targeted reduction is necessary for practical reasons, since the display area of mobile devices is very limited. A typical approach is often used in formerly large amounts of information providing deep menu structures and extensive configuration options. This, however, affects the users in their actual value-adding activities, and takes often a long time. The aim of the focal point is rather that the previous focal point system of associated knowledge needs automatically reduced information for specific operational tasks (performing a maintenance task). How does it work? The key is the context. Mobile devices are characterized not only by their connectivity, but makes intelligent use of internal sensors permanently possible contextualization of information requests. In the simplest case, the determination of the location of the user perspective allows a reduction of available information to the relevant information. Another key issue is the manner of representation of information. As the request for information the representation should not affect the user in his work. The Augmented Reality technology in the context with the superimposing of the camera image by computer-generated models and information provides an intuitive representation of data. Addressed by the context-based suite of services and information an application of the Outernet is created, whose term was introduced by the trend of research.

Step 5: Development and Implementation of an Information-Based Prototype

How will the practical solution of the information and technical system support the management of facilities especially by inspection and maintenance?
The main focus is to transfer the overall planning concept as well as the technological process into a prototype. As a result, a technical computing and engineering prototype will be created and validated in practice in a final phase.

CONCLUSIONS

The objective of the approach is to provide intuitively existing planning and operation knowledge of industrial facilities that must be inspected and maintained in the field. A virtual plan and map of the industrial facility will be created and linked with additional information based on central data bases. Therefore, the methodical and technological means and opportunities of the augmented reality were tested and will be used. The information provision is realised in mobile and context-based manner by use of semantic networks of knowledge. A 5-phase model is to pass through in order to be able to realise the approach from the early stage of planning up to the realisation of the prototypes. It consists of the developing complexes for the semantic model of the industrial facilities, the related information-logistic architecture, and the mobile and context-based information provision. In general, the final solution will open a new perspective for inspection and maintenance of industrial facilities based on integrated planning and operating systems supported by semantic technologies and augmented reality.

REFERENCES

Götze, J.; Müller, E.; Rutsch, A.; Schumann, Chr.-A. 2011. „Industrial Information Site Mapping (I²SM).” In: Dobre (Ed.): *17th European Concurrent Engineering Conference*, EUROSIS-ETI, 43-46.

Hänsch, K.; Endig, M. 2010. “Informationsmanagement in der Instandhaltung.“ In: Schenk (Ed..) *Instandhaltung technischer Systeme*. Springer Heidelberg Dortrecht London New York. 231-287.

Hwang, M. I. Information dimension, information overload and decision quality 1999. *Journal of information science*, Vol 25, Number 3, 213-218.

THESEUS press agency 2012. Das Forschungsprogramm THESEUS. URL: http://www.theseus-programm.de/de/theseus.php, Date: 01.02.2012

BIOGRAPHIES

JANEK GÖTZE, born 1974 in Karl-Marx-Stadt has a Joint Masters Degree in Industrial Engineering with Business Studies from the Chemnitz University of Technology. His majors have been Accounting, Logistics and Quality Management. Currently he does his doctorate at the Chemnitz University of Technology.

EGON MÜLLER was born in 1952, studied Mechanical Engineering and earned a doctorate at the Engineering School of Zwickau. Between 1978 and 1992, he held several positions in the automotive industry and the Engineering School of Zwickau. In 1992 he became full professor for Factory Planning at the University of Applied Sciences Zwickau. Since 2002, he is holding a professorship for Factory Planning and Factory Management at the Chemnitz University of Technology.

ANDREAS RUTSCH was born in 1980 (Plauen, Germany). He earns a Master of Science in Systems Engineering from the Chemnitz University of Technology where he still does his doctorate. Currently he is a member of research staff at the Universities of Leipzig and Zwickau.

CHRISTIAN-ANDREAS SCHUMANN, born 1957 in Chemnitz (Germany), studied Industrial Engineering at the Chemnitz University of Technology, doing his first doctor’s degree in 1984 and second doctor’s degree in 1987. He became associate professor for Plant Planning and Information Processes at the Chemnitz University of Technology in 1988. In 1994, Christian-Andreas Schumann became full professor for Business and Engineering Information Systems at the University of Applied Sciences Zwickau.

INTELLIGENT MANUFACTURING SYSTEMS BASED ON NOISE AND VIBRATION INVESTIGATION

Miron Zapciu
Department of MSP
University Politehnica of Bucharest
Spl. Independentei 313, code
060032, Bucharest, Romania
E-mail: miron.zapciu@upb.ro

Nicolae Boicea
Renault Technologie Roumanie
Sos. Pipera-Tunari, nr 2/III,
Voluntari, Ilfov, Romania
Tel: 021 6868410
E-mail: nicolae.boicea@daciagroup.com

KEYWORDS

Dynamic monitoring, signal noise-vibration.

ABSTRACT

The paper proposes an innovative idea to diagnose the technical condition of machinery and industrial equipment based on a simultaneous acquisition of vibration and noise signals, after a procedure that eliminates the factors that hide the defects. The objective is to bring new knowledge in manufacturing process control, by using dynamics signal processing and interdisciplinary knowledge in order to build, in the future, a predictive monitoring system for the machine tool. Machine vibration and noise component dominates the overall spectrum at a certain frequency, and so the overall level of vibration or noise is a useful parameter for early detection of faults. Three levels of maintenance program of machine tool were proposed. The experimentation has been validated by results based on measuring the vibration and noise signals of the milling spindle using module "tracking" of the Schenck equipment Vibroport 41.

1. INTRODUCTION

The vibration spectra has to be coupled with investigations based on in-situ operation noise. This idea could create a new service, especially for users of industrial equipment in the construction of machine tools, advanced equipment, automotive and related equipment (Zapciu and al. 2011).

The objective of this diagnostication technique is to make one of the following decisions (Teti and al. 2010):

-The machine continues to operate without taking any action;

- Having made some planned maintenance actions over time;
- Having made an analytical diagnosis of the causes that can provoke machine tool accidents;
- The machine tool should be stopped immediately to avoid an imminent crash (Girardin and al. 2010).

In normal operating condition assessment of a machine tool that stands out, the measurement for a single parameter is not enough. For example, in the medical field, there is not only a single variable that determines the health condition of a person, so in technical terms, only the individual signs of damage can be measured and a decision may be taken in general terms. The more obvious signs of damage are measured, the more accurate the assessment of the operating condition of the machine tool will be. Evaluation of operating conditions of a machine tool values by using the levels of vibration and noise is the easiest and quickest way to make a diagnosis.

Requiring low cost, this method produces reliable results and generates information for an early recognition of faults and imbalances, optimal planning of maintenance and preventive action of damage or disruption of production processes.

2. EXPERIMENTAL SETUP

Most organizations in Europe (especially in Austria, Germany, Sweden) want to have a predictive maintenance program that includes sets of experimental measurements made by means of permanently installed sensors and periodic measurements made with ultra portable instruments. Predictive maintenance can be done online from sensors installed (i.e. vibration and temperature-limited) periodically with a data logger or a combination of the two variants.

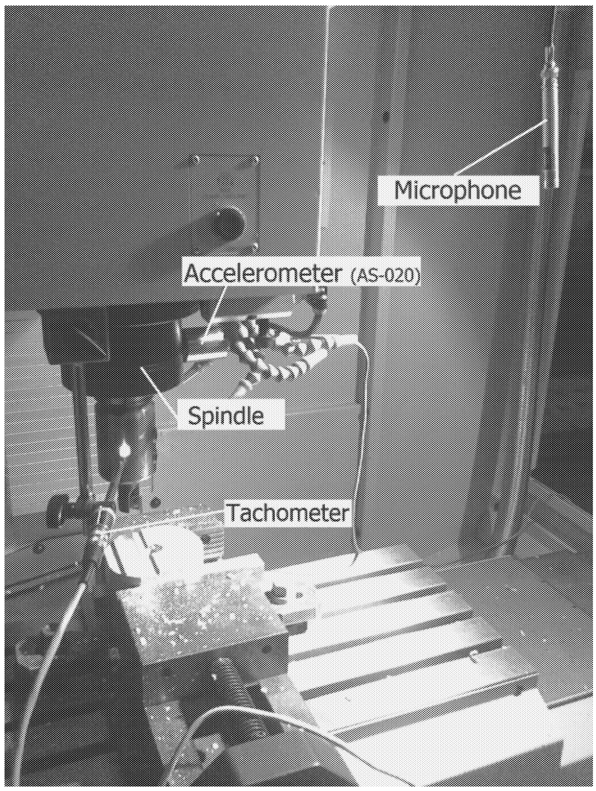


Figure 1. Vertical milling machine tool MCV 300

In the Figure 1 the machine tool used for the experimentation is represented. The frequencies characteristics of the sensors used for the experimentation have the useful domain 10 Hz – 10 kHz for this type of research on vibration/noise (AS-020 accelerometer and microphone unit type 4188-A-021).
The accelerometer was placed on the front of the spindle and the microphone was placed at 1 meter distance from the cutting tool.
Comparing general amplitude of vibrations recorded at regular intervals is possible using other specialized equipment (e.g. data collector 2526 of the company Brüel & Kjaer) to get another example of basic predictive monitoring program (Ai and al. 2011).

3. EXPERIMENTATION

The paper intends to bring new knowledge in manufacturing process control using dynamics signal processing and interdisciplinary knowledge in order to build in the future a predictive monitoring system for the machine tool (Zapciu and al. 2008).
Predictive monitoring programs have three main objectives:
- Warning as soon as possible of potential defects in equipment with continuous monitoring systems
- Monitoring the technical condition of the machine or equipment on the general level of vibration or noise
- Early warning of defects that can remain hidden, using advanced features such as a CPB spectrum.

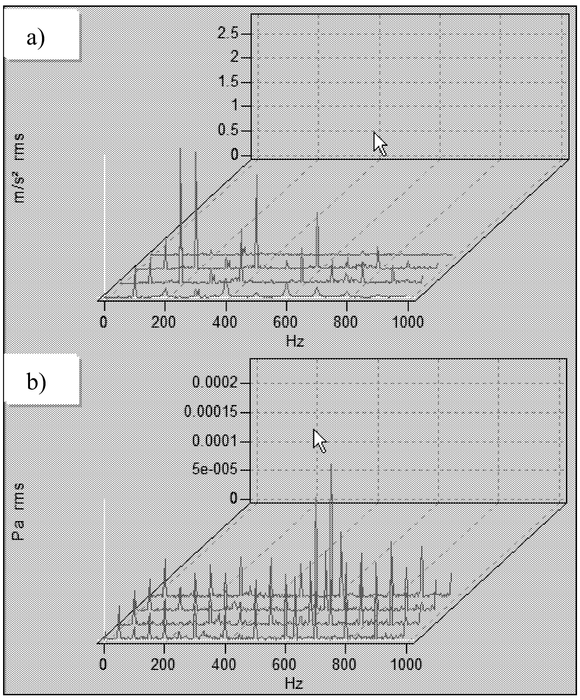


Figure 2. Frequency spectrum of vibration (a) and noise (b)

In order to eliminate environment noise signal during the measurements a filter was applied. Filter was conceived using mathematical average noise amplitudes for four signals acquired over time (Figure 2). This filter was applied to measure the noise signal during the milling process of aluminum in the following conditions:

-Cutting depth of 2 mm; milling tool with 2 inserts and diameter of 25 mm;
- Spindle speed equal with 6000 rpm.

Noise measurements were performed simultaneously with vibration measurements. Four signals were acquired over time. Figure 3 presents the vibration spectra for the four measurements (acquired signal was periodically in time: 0; 3; 6 and 9 seconds respectively). Figure 4 shows the importance of signal filtering to eliminate the noise.

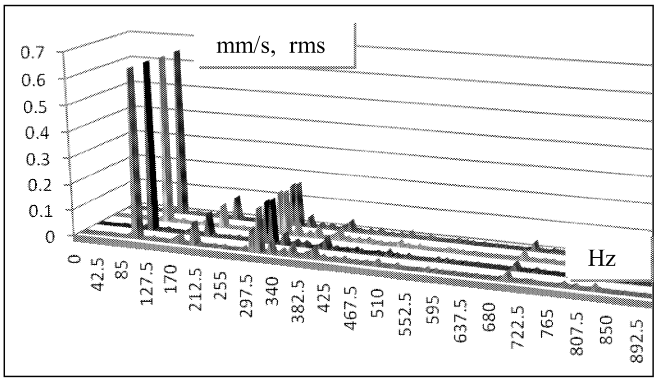


Figure 3. Vibration spectrum during acquisitions

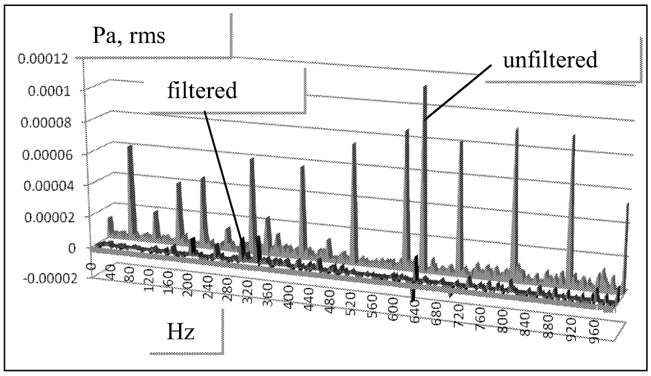


Figure 4. Noise signal (unfiltered and filtered)

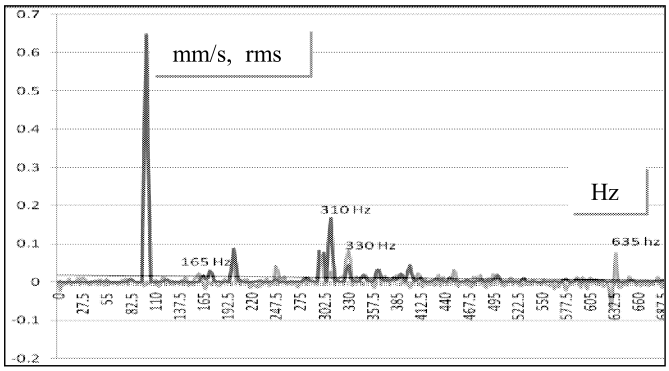


Figure 5. Combined signal vibration-noise

By analyzing the graph in the Figure 5 the following remarks ensue:

- Frequency of 100 Hz corresponds with the spindle speed frequency that is 6000 rpm; it shows 3 peaks frequency of 165 Hz, 310 Hz and 330 Hz with both corresponding in the noise and vibration spectrum;

- The frequency of rotation of the spindle is not present in the noise output signal.

The results are based on the autocorrelation of two signals R(τ) by using the relation (1):

$$R(\tau) = \lim_{T\to\infty} \frac{1}{T}\int_0^T y(t)y(t+\tau)dt \quad (1)$$

White noise type signals lose their correlation when τ departs from 0. As a threshold matter, a sinusoidal signal *y(t)=A*sin(ωt+φ)* reaches peaks of autocorrelation for τ values equal to the period of the sinusoidal signal $R(\tau)=(A^2/2)\cos(\omega t)$, so is no decrease of parameter τ.

Between these limits are all other temporal signals with different attenuations of autocorrelation (Chementinand al. 2008). If the time signal is a harmonic signal covered by noise, the autocorrelation function could detect harmonic signal as the autocorrelation function tends to harmonic signal at large values of the τ parameter.

In general, most of Predictive Maintenance programs incorporate a variety of parameters to characterize accurately the technical state of the machine and to provide early warning of significant changes (Marichal and al. 2011).

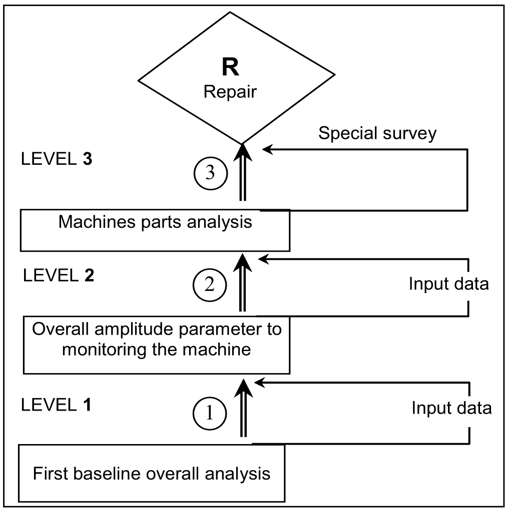


Figure 6. Levels of maintenance

The program of maintenance proposed by this paper has several levels (Figure 6). The base level is one that checks the overall level of vibration and noise using the standard values. The last level is to obtain the causes, detection components that lead to the failure of the monitored machine.

CONCLUSION AND FUTURE WORK

The main objective of this research and development project in partnership University Politehnica of Bucharest - Renault Technologie Roumanie is to propose a predictive maintenance for the machinery and industrial equipment. In this context, the current issue is extremely important and allows in the future the development of a predictive maintenance service. The secondary objective of the project is finding a dynamic model of the spectrum to eliminate those frequencies is not due to defects.

This action has been validated so far by the very encouraging experimental results based on measuring the vibration of the milling spindle using module "tracking" of the equipment Vibroport 41 (Schenck).

When the vibration or noise component dominates the overall spectrum at a certain frequency, the overall level of vibration or noise is a useful parameter for the early detection of faults and other operational elements in the mechanical parts of machines and equipment in mechanical and industrial engineering.

REFERENCES

Zapciu M., K'Nevez J-Y., Gérard A., Cahuc O. and Bisu Cl.Fl. 2011. "Dynamic characterization of machining systems". *In Rev. International Journal of Advanced Manufacturing Technology*, 57:73–83, DOI 10.1007/s00170-011-3277-7, Volume 57, Issue 1, pag. 73-83, ISSN 0268-3768, ISI Springer Edition.

Girardin F., Remond D. and Rigal. J.F. 2010. "A new method for detecting tool wear and breakage in milling", *International Journal of Material Forming*, Springer, Vol.3, pp.463-466.

Teti R., Jemielniak K., O'Donnell G. and Dornfeld D. 2010. "Advanced monitoring of machining operations". *CIRP Annals - Manufacturing Technology*, Vol. 59, pp.717–739.

Chementin X., Balaers F., Cousinard O. and Rasolofondraibe L. 2008. "Early detection of rolling bearing defect by demodulation of vibration signal using adapted wavelet". *Journal of Vibration and Control*, Vol.14, no.11, pp. 1675-1690.

Marichal G.N., Artes M. and Garcia-Prada J.C. 2011. "An intelligent system for faulty-bearing detection based on vibration spectra". *Journal of Vibration and Control*, Vol.17, pp.1675-1690.

Chiementin X. 2007. "Localisation et quantification des sources vibratoires dans le cadre d'une maintenance préventive conditionnelle en vue de stabiliser le diagnostic et le suivi de l'endommagement des composants mécaniques tournants: application aux roulements à billes". *PhD Thesis*, University of Reims Champagne Ardennes, France.

Peigné G. 2003. "Etude et simulation des effets dynamiques de la coupe sur la stabilité de la coupe et la qualité géométrique de la surface usinée". *PhD Thesis*, Institut National Polytechnique de Grenoble, France.

Ai C.S., Sun Y.J., He G.W., Ze X.B., Li W. and Mao K. 2011. "The milling tool wear monitoring using the acoustic spectrum". *The International Journal of Advanced Manufacturing Technology* DOI: 10.1007/s00170, Vol 57.

Bisu C.F., Darnis P., Gérard A. and J-Y Knevez. 2008. "Displacements analysis of self-excited vibrations in turning". *International Journal of Advanced Manufacturing Technology*, Vol.44 (1-2), pp. 1-16.

Thevenot. V. 2005. "Contribution à la maîtrise des phénomènes vibratoires en usinage de parois minces: application à l'usinage de pâles aéronautiques". *PhD Thesis*, Institut National Polytechnique de Toulouse, France.

Girardin F. 2010. "Etude de l'usinage de matériaux performants et surveillance de l'usinage". *PhD Thesis*, Institut National de Sciences Appliquées de Lyon, France.

Zapciu M. and Paraschiv M. 2007. "Predictive maintenance and use of tracking concept to analyze dynamics of machine tool spindle". *The 11th International Conference Modern technologies, quality, restructuration - TMCR'2007*, Chisinau, Modavia, May 31th – June 3th.

Zapciu M., K'Nevez J-Y. and Gérard A. 2007. "Using tracking analysis of predictive maintenance concept in order to obtain dynamics of machine tool spindles". *International Conference on Advanced Manufacturing Technologies ICAMaT 2007*, Sibiu, Romania, 12-14 July.

Zapciu M., Gérard A., K'nevez J-Y., Cahuc O. and Bisu C. 2008. "Experimental dynamic characterization of machine tool spindle". *The 19th International DAAAM SYMPOSIUM. "Intelligent Manufacturing & Automation: Focus on Next Generation of Intelligent Systems and Solutions"* 22-25th October.

KNOWLEDGE ENGINEERING

METAKNOWLEDGE FOR INTELLIGENT SIMULATION

Tudor Niculiu, University *Politehnica* Bucharest, Electronics, Telecomms & IT Faculty, +40 402 4885, tudor-razvan@ieee.org

Maria Niculiu, University Bucharest, Faculty for Foreign Languages, +0722 787 333, mariaoficialfac@yahoo.com

Sorin Cotofană, Delft University of Technology, Faculty of EE, Mathematics & CS, +31 15 278 6267, S.D.Cotofana@ewi.tudelft.nl

Keywords: Intelligent Simulation, Simulated Intelligence, Hierarchy Types.

Abstract:

Dear God, Search and research our world,
made by Your Right and help us complete it

Orthodox Pantocrator

Einstweilen bis den Bau der Welt Philosophie zusammenhält, , erhält sich das Getriebe durch Hunger, Furcht und Liebe

Friedrich Schiller

Das schöne wahre Gute.

Johann Wolfgang von Goethe

Faith and intelligence form the ☯ of our life:
Way, Truth, Life // frontal view
Human = human (Humanity);
human ∈ Faith × Intelligence → Faith × Intelligence;
Humanity = (Set of humans,
eternity / evolution-oriented Structure).
evolution ∈ (Hunger, Fear, Love) × (Technology,
Science, Art) → (Technology, Science, Art).
Mathematics ⊂ Art = Human::beauty-oriented activity (
Science, Technology).
Physics = natural Science ∪ social Science =
Human :: truth-oriented activity (Art, Technology).
Engineering/ Technology = Human :: good-oriented
activity (Art, Science).
The history of the common measure could be
synthesized along the following line:

... ← Philosophy ← ... ← Culture ←
specific Knowledge ← Economics ← Force.

Simulation∈Behavior × Structure ⇐ Knowledge
// "⇐" stands for "implies"
Knowledge ⇐ Intelligence :: information()
// "::" stands for "Class :: method"
Imagination ⇐ | Intuition - Consciousness |
// "()" stands for "depending of"
Intention ⇐ | Inspiration - Adaptability |
// "| x -y |" stands for "difference between"
Consciousness ⇐ reflexiveAbstraction (Intention);
Adaptability ⇐ simplifyingAbstraction
(Imagination)
Intelligence =
Consciousness × Adaptability × Intention &
Faith = Inspiration × Intuition × Imagination,
are complementary parts of the human mind,
separated by
Conscience = Consciousness × Inspiration.

ARGUMENT

Faith is associated to the right human brain hemisphere. Intuition is the main part of the dark yin, inspiration the dynamical shaped interface to intelligence, whereby the white point, link to the left part, stands for imagination. Intelligence corresponds to the left human brain hemisphere. Adaptability is the main part of the light yang, consciousness the variable nuanced interface to faith, whereby the dark point, link to faith, signifies intention. Consciousness is self-awareness of individual faith and intelligence, as well as of the relation to the local context (society) and to the global one (universe). To appear it needs self-knowledge, what could result from community consciousness featured by an eternal human structure, e.g., from the past, shepherds, farmers, sailors, Africans, Amer-Indians, Asians, Australians, .. Each individual recognized himself in his cohabitants, being adaptable and having a lot of intuition. Evolution of the common measure is conditioned by the conscient construction of correspondingly intelligent agents to manage the lower stages, as industry enabled the mechanization of agriculture followed by the concentration on economics.

Evolution implied a multiple *Divide et Impera et Intellige* for consciousness associated to generating the lacking *components* of the mind, then assisted by them:

- individual-social-universal conscience→*inspiration* (subjective-contextual-objective)↙
- space-time (structure-behavior) → *imagination*↙
- discrete-continuous (natural-real) → *intention*
- beauty-truth-good (art-science-technology)↙.

Mathematics discovers and studies fundamental types of structures: (algebra, topology, order), and fundaments (construction, orientation, understanding). These are rarely separately used, example of correct and complete integration for science and technology[3]. Physics[8] should integrate its fundamental forces theories, but also, as chapters, all others natural sciences and the social sciences, leading them to really apply mathematics. Social sciences study a universe, as complex and nondeterministic as the natural one, so mathematics is at least as important to them as for natural sciences. This way, science would also be a better inspiration source for mathematics. Engineering has to be closely related to mathematical approach and integration of parts, not only to mathematical techniques; as reality contains the abstract ideas, even if physics could explain everything discretely, the power of continuum can not be forgotten, i.e., analog engineering should not be neglected in modeling and simulation.

The convergence process of evolution demands struggle against time, with structure as ally. Consciosness[2] needs, more than discrete recurrence, continuous feedback. Social and individual conscience are mostly divergent nowadays, i.e., we only performed *Divide et Impera*, neglecting *Intellige*. It's high time to correct it.

SEARCHING FOR CONSCIOUSNESS

Evidently, the anterior relations are oversimplified in order to move towards intelligent simulation. Although we claim they are intuitive and hope they are inspired, to begin, we neglect the essential but too primitive to understand intuition and inspiration, so (see further) formalizing reflexive abstraction by the knowledge hierarchy type and simplifying abstraction mainly by the simulation hierarchy type, it follows that:

Consciousness= knowledge(simulation(Consciousness))

i.e., a fixed-point relation suggesting that we could model consciousness associating to any hierarchical level of the construction process a knowledge level. To solve the fixed-point problem we have to build a metric space where knowledge ° construction is a contraction, i.e., elements implied in the construction should get closer to one another in the formal understanding of the formal construct. If, even in the sketch, we consider general functional relations between the essential parts of the faith-assisted intelligence, it results:

Consciousness = knowledge (intention (Inspiration, simulation (imagination (Intuition, Consciousness))))

A generic modeling scheme defines the model universe, e.g., a mathematical theory, a programming paradigm. Every entity has behavior (relations to other entities) and structure (internal relations). Behavior can be functional (context-free) or procedural (context-dependent). An algorithm is an entity that can be computer simulated, so it represents computability, bottom-up (construction, design, plan) or top-down (understanding, verification, learning).

The algorithmic approach is equivalent to the formal one: If a sentence of a formal system is true, then an algorithm can confirm it. Reciprocally, for a verification algorithm of the mathematical sentences, a formal system can be defined, that holds for true the sentences in the set closure of the algorithm's results towards the operations of the considered logic.

David Hilbert's formal systems, *Alonzo Church*'s λ-calculus, *Alan Turing*'s machines, *Stephen Cole Kleene*'s recursive functions, *Emil Post*'s combinational machines, *Noam Chomsky*'s grammars, *Aleksandr A. Markov*'s algorithms, are the best-known equivalent formalisms for computation, i.e., algorithm and computability[4].

RESEARCHING FOR CONSCIENCE

The alternative ways followed to extend the computability concept can be compared to approaches known from German dramas and novels:

1. Faust (*Johann Wolfgang von Goethe*): heuristics - risking competence for performance, basing on imagination, confined to the mental world.
2. Das Glasperlenspiel (*Hermann Hesse*): unlimited natural parallelism - remaining at countable physical suggestions, so in the Nature.
3. Der Zauberberg (*Thomas Mann*): hierarchical self-referential knowledge - needing to conciliate the discrete structure of hierarchy with the continuous reaction, hoping to open the way to Reality.

They concentrate respectively on the mental world of the good managed by technology, the physical world of the truth researched by science and Plato's world of the beautiful abstractions discovered by art. Intelligence in evolution is the faculty to:

- synthesize/ analyze/ modify abstract objects, i.e., ideas;
- analyze/ modify natural objects and synthesize/ modify artificial objects in the physical world
- synthesize/ analyze/ modify representations for the mental world[6];

especially hierarchical reflexive: ideas about ideas and how to get to ideas, objects to synthesize/ analyze/ modify objects, representations on representations and how to build/ understand representations. Evolution is linked to the initial design of mental faculties for surviving of the whole system - not for abstract thinking, but also to the space-time context supposed by communication between intelligent agents.

HIERARCHY TYPES

We follow the mathematical paradigm of intelligent simulation by functionally modeling the self-aware adaptable behavior for intelligence simulation. The integration between discrete and analog is again needed, for a most soft adaptability and for consciousness simulation as continuous recurrence, i.e., analog reaction. Knowledge and construction hierarchies co-operate to integrate design and verification into simulation; object-oriented concepts are symbolized to handle data and operations formally; structural representation of behavior manages its realization.

Hierarchy types open the way to simulate intelligence as adaptable consciousness, by integrating the system and the metasystem. Hierarchy is the syntax of abstraction.

Abstraction and hierarchy are semantic and syntactical aspects of a unique fundamental concept, the most powerful tool in systematic knowledge; this concept is a particular form of *Divide et Impera et Intellige*; hierarchy results of formalizing abstraction. Hierarchies of different types correspond to the kind of abstraction they reflect (the abstraction goal):

- Class hierarchy (↑concepts) ↔ virtual framework to represent any kind of hierarchy, based on form-contents, modularity, inheritance, polymorphism.
- Symbolization hierarchy (↑mathematics) ↔ stepwise formalism for all kind of types, in particular also for hierarchy types.
- Structure hierarchy (↑strategies) ↔ stepwise managing of all types on different levels by recursive autonomous decomposition, following closely the principle *Divide et Impera et Intellige*.
- Construction hierarchy (↑simulation) ↔ simulation (= design/ verification) framework of autonomous levels for different abstraction grades of description.
- Knowledge hierarchy (↑theories) ↔ reflexive abstraction ("self-referential", "a deeper sense"), aiming that each level has knowledge of its inferior levels, including itself.

The knowledge hierarchy type offers a way to model consciousness, as the inital solution for conscience. The first idea is to consider/ remember that reality is more than nature, as the continuum of IR is more powerful than the discrete universe of IN. Understanding and construction have correspondent hierarchy types: their syntax relies on classes, the meaning on symbols, and their use on modules (Fig.1). The theory of categories offers formalism for hierarchy types. Constructive type theory permits formal specification and formal verification generating an object satisfying the specification.

Example: The classical activities in complex systems simulation, that regard different levels of the construction or knowledge hierarchy, can be expressed symbolically then represented object-oriented and simulated structurally (Fig.2). Complex simulation needs consistent combination of mathematical domains and an intelligent compromise between consistence and completeness.

METAKNOWLEDGE

Recurrence of structures and operations enables approximate self-knowledge (with improved precision on the higher levels of knowledge hierarchies). Recurrence is confined to discrete worlds, while abstraction is not. This difference suggests searching for understanding based on mathematical structures that order algebra into topology (Fig.3). A continuous model for hierarchy levels, without loosing the hierarchy attributes, would offer a better model for consciousness and intelligence. Recurrence of structures and operations enables approximate self-knowledge (with improved precision on the higher levels of knowledge hierarchies). Recurrence is confined to discrete worlds, while abstraction is not. This difference suggests searching for understanding based on mathematical structures that order algebra into topology (Fig.3). A continuous model for hierarchy levels, without loosing the hierarchy attributes, would offer a better model for consciousness and intelligence. Knowledge is based on morphism mapping the state-space of the object-system onto the internal representation of the simulator. An intelligent simulator learns generating and validating models of the object-system. Therefore: representation for design and verification should be common; the algebraic structures on which the different hierarchy types are based on should be extended to topological structures; the different simulation entities should be symbolic, having attributes as: type, domain, function. A topology on the space of symbolic objects permits grouping items with common properties in classes[9]. It results a dynamic internal object-oriented representation that can be adapted to the different hierarchy types.

CONCLUSIONS

Consciousness simulation demands transcending the present limits of computability, by an intensive effort on extensive research to integrate essential physical and mathematical knowledge guided by philosophical goals. A way to begin is hierarchical analog-digital simulation. Applying *Divide et Impera et Intellige* to hierarchy types, using the formalism of categories, reveals their comprehensive constructive importance based on structural approach, symbolic meaning, object-oriented representation. Formalizing hierarchical descriptions, we create a theoretical kernel that can be used for self-organizing systems. Simulability is computability using the power of continuum. There are enough positive signs for this from analog electronics, control systems, mechatronics. Real progress towards this way of computation needs unrestricted mathematics, integrated physics and thinking by analogies. Evolution needs separation of faith and intelligence, understanding and using consciously more of faith's domain, integrating them to human wisdom, to be divided further to get more human. Metaphorically phrased, our problem is that:

Uncountable are God's ways.

REFERENCES

1. P. Ageron 2001: Limites inductives point par point dans les categories accessibles, Theory and Applications of Categories 8, 11, 313-323.
2. R. Amoroso et al. (eds.) 2000: Science & the Primacy of Consciousness, Intimation of a 21st Century Revolution, Noetic Press.
3. L. Blum, F. Cucker, M. Shub and S. Smale 1998: Complexity and Real Computation, Springer.
4. D Hofstadter 1979: Gödel, Escher, Bach, The Eternal Golden Braid, Vintage Books.
5. K. Keutzer et al. 2000: Orthogonalization of Concerns & Platform-based Design, IEEE TCAD 19, 12, 1523-1543.
6. R. Penrose 1994: Shadows of the Mind, Consciousness and Computability, Oxford University Press.
7. W. Rudin 1973: Functional Analysis, McGraw Hill.
8. J. F. Traub 1999. A Continuous Model of Computation, PhysicsToday, 39-43, May.
9. B. Zeigler, H. Praehofer, T. Kim: Theory of Modeling and Simulation, Academic Press, 2000.

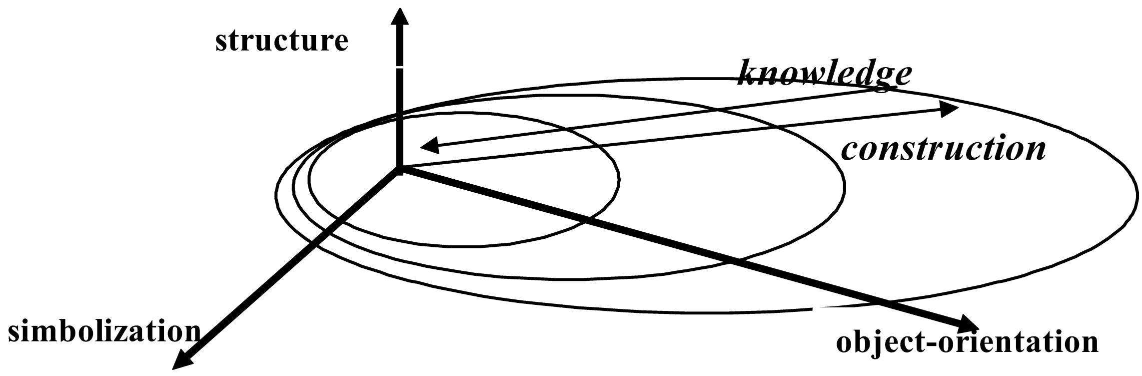


Figure 1: H - diagram

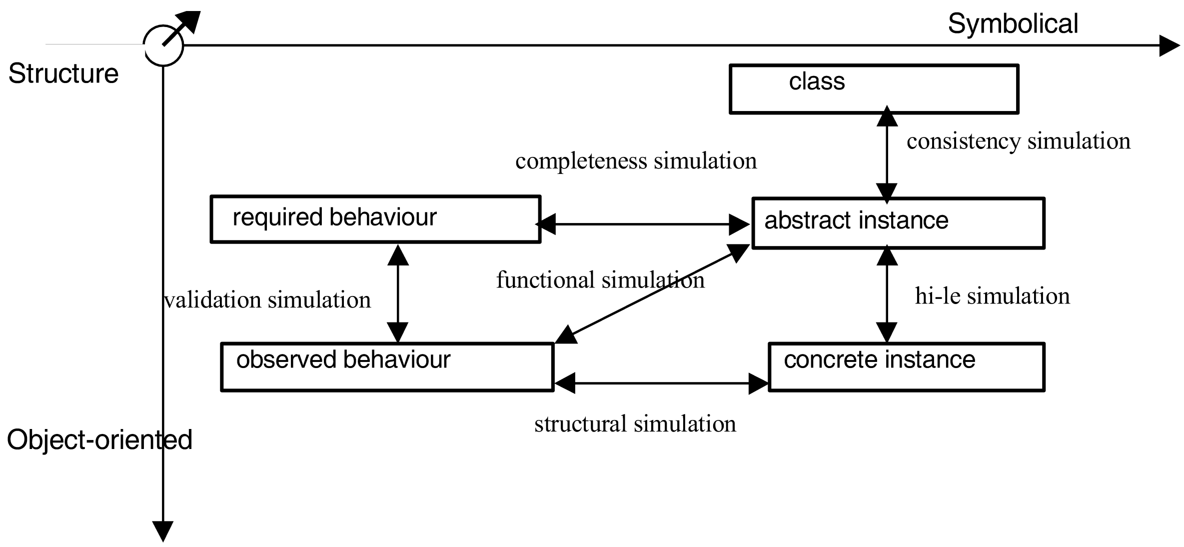
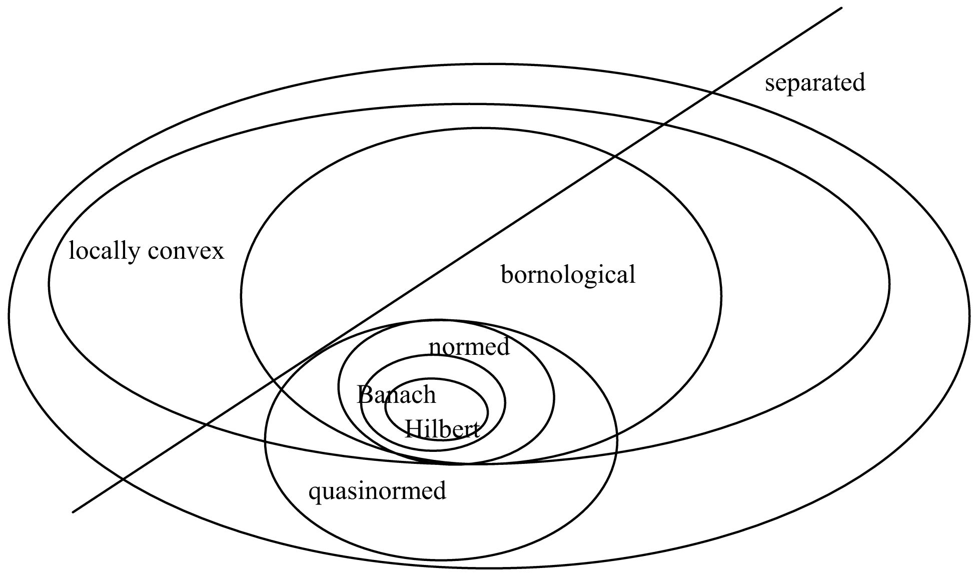


Figure 2: Hierarchical Simulation Paradigm: representation

Figure 3: Topological Vector Spaces/ Algebra



PRACTICAL SOLUTIONS FOR SMALL HYDRO POWER PLANT DESIGN

Vlad Florin Pîrăianu
University Politehnica of Bucharest
Splaiul Independentei no. 313
RO 060042 Bucharest, Romania
E-mail: vlad.piraianu@gmail.com

Cornel Ilinca
Technical University of Civil Engineering Bucharest
Lacul Tei no. 122 - 124
RO 020396 Bucharest, Romania
E-mail: cornel@utcb.ro

KEYWORDS
optimization, renewable energy, genetic algorithms

ABSTRACT

This paper aims to present the main results of a technical report for the construction of a small hydroelectric power plant and the results of a state of the art design based on the optimization scheme in order to achieve the maximum efficiency of the power plant and minimizing the cost of the investment.

INTRODUCTION

This article aims to show how practical experience, combined with scientific and theoretical knowledge and experience can work together to achieve the best suited and optimal solution for the design and works completed in order to build in an efficient manner a small hydroelectric power plant (S.H.P). This article is based on the technical report that shows the irregularities in design and construction of the small hydroelectrical power plants. Having in mind that the design is a key element in the development of small hydroelectric power station, considered one of the most efficient renewable energy source, we believe that modern design has to take into consideration certain elements to ensure the safety in operation both for hydrotechnical construction (intakes, weir, runaway channel, etc.) and for the technological equipment (penstock, trash-rack, inlet valve, turbine, generator, ancillary systems, etc.). In Romania, energy produced by hydroelectric power plants that have less than 10 MW installed capacity is considered by European legislation to be renewable energy resource (together with wind, solar, biomass, etc). Therefore any investment in such projects, has a proposed scheme for promoting the energy from renewable sources, with **G**reen **C**ertificates (GC). According to the law, for new hydroelectric power plants is given a number of 3 GC per each MWh delivered to the grid, with a price of each GC between 27 and 55 EUR, established by the National Energy Regulation Authority (A.N.R.E). Having an attractive framework for promotion of investment in renewable energy has made place for a large number of investments.

OPTIMIZATION – A TOOL FOR DESIGN AND OPERATION

If a system is working properly, and good results are obtained, whether is related to the design of an installation or to the functioning of a device, system or power plant exploitation, does not mean that it is working optimal. Transposing this issue to the design phase of a hydroelectric power plant project, if the parameters achieved are good or satisfying and accepted by the beneficiary and/or investor it doesn't mean that there is no room of improvement and optimization. For the complex designing issues, which is the same no matter what is designed, some aspects of the optimization has to be established: what is the purpose of the optimization, the development of the mathematical model, the determination of limits (to ensure that the algorithm will give available and realistic solutions), the establishment of the scope (target) function and the method of optimization.

In the design phase, the determination of the optimal solution for parts and/or the entire power scheme should be based on the following:

- Target function (e.g. the overall cost function, cost of maintenance and operation, cost of installation, technical parameters, etc.);
- The main objective of the optimization: a maximization problem or a minimization problem (e.g. maximization of energy produced, minimization of total cost, etc.);
- Secondary objectives can be taken into consideration (e.g. first objective the maximization of produced energy and secondary objective the minimization of total cost).

Determining the optimal design parameters of a power plant and/or a cascade of (small) power plants is a complex and delicate problem from the following reasons:

- Economical aspects of material and work force;
- Difficulty to estimate and foreseen from the design phase all the critical aspects/problem which may occur;
- When taking into consideration the cost of operation and maintenance and the optimization of the operation, it is hard to determine the flow (stochastic nature), non linear equation for computing the power, energy and costs.

Because of these issues and many other, the solution mostly suited for the optimization of design and operation of small hydroelectric power plants is based on genetic algorithms (GA). GA belongs to stochastic search methods used to approach extreme complex optimization problems, being the most robust of all algorithms. In fact, any task which must be completed can be look like resolving a problem, and resolving the problem means looking after a solution in the infinite potential solutions and finding "the most suitable" one. Therefore, any task can be assimilated with an optimization process. The principle of GA is that every possible solution is considered a population. Based on Darwin principles, the child is better than the parents in order to assure the preservation of species and the survival of the best. Every "child" solution (a possible solution of the optimization process), is obtained as the next generation with selected "parents" (solutions from the current area of available solution that are able to breed). The individual solutions for the problem are selected using a fitness-based function in such way they are fitted to be close to optimal result. This implies having a fitness function. There are methods of selection from the wide area of solutions, the ones that have the best results, and there are methods of selecting random sample population which may lead to a time consuming optimization process. The child solution is obtained by *reproduction* of the selected spectrum of available solutions. The reproduction in genetic algorithm optimization is accomplished through genetic operators: **crossover** (named also recombination) and/or **mutation**. The obtained "child" shares most of the characteristics of its "parents". The process continues by selecting "parents" and obtaining "child" solutions until a new population of solutions of satisfactory size is obtained and is the most suited for the proposed design problem. Usually, the reproduction methods used two parents as the example from the nature, but there are some researchers who suggest that more than two parents generate higher quality chromosomes (solutions) which in the end reduce the convergence time for solution. [6],[7]. The basic principle of GA is summarized in diagram 1.

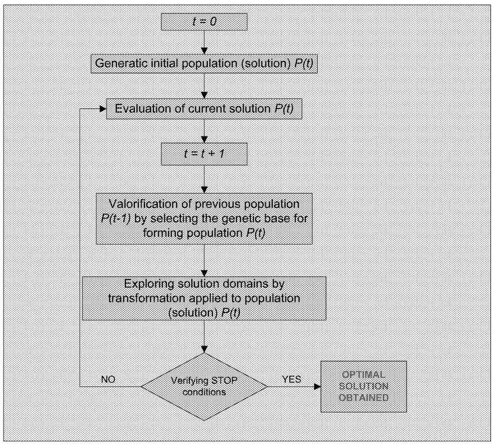


Diagram 1 – GA sketch

The genetic algorithm can be successfully used to design the best scheme of one hydroelectric small/regular power plant and can be used as well to determine the optimal politics of exploitation of hydroelectric power plants (or cascades of power plants). Some of the solutions given by the authors to the problems that occurred in the construction phase of a small hydroelectric power plant, were based on optimization process to ensure the best economical but also technical results. The cost optimization was made by determine the main dimensions and technical parameters of the individual construction (e.g. water intake, selected flow value, length of pipe, diameter of pipe, material of pipe, output power and energy etc.). The purpose of this article is to present a study case based on the execution of the power plant. Some aspects regarding optimal design of main structures are presented.

TELEAJEN – GURA VITIIOAREI S.H.P.

The studied small hydroelectric power plant is situated on River Teleajen, affluent of the River Ialomita, near Valenii de Munte city, in Romania (see Table 1).

Table 1: Main parameters of SHP

Intake Water level [Black Sea Level]	332	m
Power House level [Black Sea Level]	293	m
Net Head	31	m
Penstock diameter	2200	mm
Penstock length	4900	m
Average Flow	9.5	m^3/s
Installed discharge	12	m^3/s
Power	3.9	MW
Energy	8.5	GWh

HYDROLOGICAL DATA ANALYSIS

The hydrological data obtained by Romanian National Water Administration are presented in Table no. 2.

Table 2: Hydrological Data

Average Flow	6.04	m^3/s
Maximum Flow 0.1%	996	m^3/s
Maximum Flow 1%	577	m^3/s
Maximum Flow 5%	310	m^3/s
Maximum Flow 10%	230	m^3/s

The average flow given by official hydrological data in table 2 is smaller than the average flow presented in the feasibility study (Table 1). Therefore the selected installed flow (12 m3/s) was chosen based on wrong hydrological raw data.

PENSTOCK DESIGN

The penstock of Teleajen SHP is made of semi-buried welded steel pipes, with 9 mm wall thickness and interior diameter of 2200 mm and has a total length of 4958.43 m. The pipe inside diameter (ID) is to small from optimal value obtained by optimization algorithm. The optimization algorithm was developed to give a range of diameter values in order to select from the existing pipes on the open market, the one that will ensure the highest return of investment. For the installed discharge, the inside diameter should be between 2400 mm and 2500 mm in order to minimize linear losses which leads to power loses. Fig. 1 presents the net head (less than 30 m) for ID 2200 mm, with linear losses of more than 25% of the gross head.

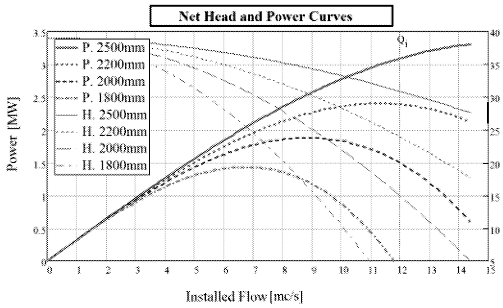


Fig. 1. Power and net head curves

The optimal solution computed by the authors, is an installed flow of 9 m^3/s for a 2200 mm ID for the penstock and a maximum output power of the turbines of 2100 kW.

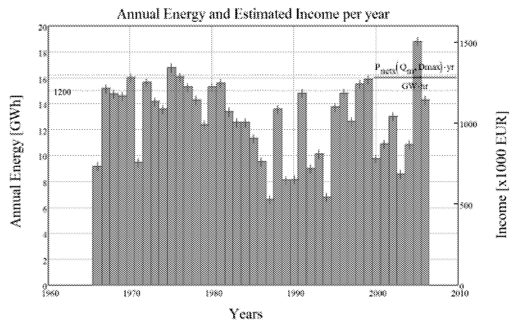


Fig. 2. Annual Energy produced and Estimated Income per year for a multi-annual hydrological data series

WATER INTAKE

The water intake (Fig. 3) has the spillway weir higher than normal (over 2 m). This over dimensioning lead to an increase of the construction costs with more than 50%. An optimal solution given is between 1,4 – 1,5 m.

Fig. 3. Water intake – weir and trash rack area

The energy dissipation structure is dimensioned for a much higher version of the specific flow and is not taking into consideration the specific phenomena of "hydraulic jump". The optimal solution for the dissipation structure should be at least 10% smaller.

Fig. 4. Energy dissipation structure

The stilling basin has five chambers and was designed for a flow of 20 m^3/s and for retained of particles of less than 0,5 mm, although the installed discharge is 12 m^3/s and the proposed turbines are Cross Flow type that have an acceptance of sand particles of max. 20 mm. These elements lead to an increase of costs with more than 75%.

Fig. 5. Settling basin – over dimensioned

For the settling basin, the optimal values were computed as follows:

- for the speed of sedimentation $w_d = 94.4\ m^3/s$ according to particles of sand with a diameter of 1 mm;
- a speed of v = 0.8 m/s has to be taken into consideration in order to prevent the freezing during the winter time;
- height of water in the settling basin Hu = 2 m;
- useful area of the section of the settling basin:

$$A_u = Q_i / v = 15\ m^2 \quad (1)$$

- width of settling basin:

$$b = A_u / H_u = 7.5\ m \quad (2)$$

- length of settling basin with deterministic method:

$$L_d = H_u \times v/w_d = 19.949\ m \quad (3)$$

- length of settling basin with assuring coefficient of 1.3 should be 22 m;

CONCLUSIONS

Nowadays, many non-governmental environmental agencies published a series of "attacks" to the S.H.P. They state that construction of the hydraulic structures in the river bed, affects negatively the ecosystems and their balance. Therefore rules are applied while construction and in operation (flow of servitude, fish pass, etc.). From environmental point of view, we consider that turbines with higher efficiency has to be promoted in order to maximize the use of water to it's purpose, energy production. This turbines can maximize the energy produced with almost 10-12% for the same used volume of water.

REFERENCES

[1] Ernest F. Brater, and others, 1996. "Handbook of Hydraulics for the Solution of Hydraulic Engineering Problems" – Seventh Edition. Mc Graw Hill.

[2] Richard G. and others, 2008. "Shigley's Mechanical Engineering Design" – Ninth Edition. Mc Graw Hill.

[3] Radu Popa and others, 2003. "Optimization of exploitation for the power plants" – Technical Edition – Bucharest.

[4] Puiu O., and others, 2000. „Economics and Management of material and energetics resources", Pitesti

[5] Eiben, A. E. and others. 1994. "Genetic algorithms with multi-parent recombination". PPSN III: Proceedings of the International Conference on Evolutionary Computation. The Third Conference on Parallel Problem Solving from Nature.

[6] Ting Chuan-Kang (2005). "On the Mean Convergence Time of Multi-parent Genetic Algorithms Without Selection". Advances in Artificial Life: 403–412. ISBN 978-3-540-28848-0.

ESTIMATION BY SIMULATING THE NET HEAT TRANSFER RATE INTO AQUATIC ECOSYSTEMS

Gabriela E.Dumitran and Liana I.Vuta
Department of Hydraulics, Hydraulic Machinery and Environmental Engineering
University POLITEHNICA of Bucharest
313, Splaiul Independentei, Bucharest,Romania
E-mail: dumitran@hydrop.pub.ro

KEYWORDS
Lakes, heat flux, mixing, solar radiation, water temperature.

ABSTRACT

Studies on the evolution of water temperature as influencing factor for water quality processes use complex models for approximating the total net flux of heat through water-air interface. This paper proposes a complex model to calculate the direct solar radiation on clear sky, based on astronomical formula that takes into account explicitly the Sun's declination, the Sun's local hour angle and local mean time of rising/setting. This model was tested over one year using field data from Golesti reservoir – Romania. The case study presented in this research provided a good opportunity for testing the model. The simulation results agree well with the observed data.

INTRODUCTION

Transport and mixing phenomena are among the important processes in natural systems and one of dominate mixing forces providing energy are meteorological conditions (Imberger and Patterson 1990). For surface water aquatic ecosystems the temperature distribution in time and in depth (for lakes) and along the water course (for rivers) is influenced by heat exchanges between water mass and atmosphere. These heat exchanges along with the kinetic energy of wind action, are the dominant factors which control the thermal regime, namely the dynamic of the analyzed ecosystems.
This paper propose a complex model for estimating the net heat transfer rate at the interface of an aquatic ecosystem, taking into account as many factors of the global heat balance possible. For aquatic ecosystem the net heat flux into the water surface depend on both the internal hydromechanical behavior of the water body and the physics of its interaction with the overlying air mass (Fisher et al. 1979; Charuchittipan and Wilson 2009). The total solar radiation is reduced by attenuation through the atmospheric column (absorption and scattering in the atmosphere) and by clouds interception. The residual radiation which reach the water surface is called net solar radiation (Oswald and Rouse 2004). At the interface of a water body the heat exchange is done by simultaneous processes of radiation, evaporation and conduction, thus the net heat flux into the water surface can be calculated as follows:

$$H_w = H_{sn} + H_{an} - (H_b \pm Hc \pm H_e) \qquad (1)$$

where H_{sn} is net solar shortwave radiation into the water surface, H_{an} is net atmospheric long-wave radiation into the water surface, H_b is long-wave back radiation from the water surface, H_c is conductive heat flux from the water surface, and H_e is evaporative heat flux from the water surface.

METHODOLOGY

The heat fluxes generated by solar and atmospheric radiations are considered as net fluxes, taking into account the radiation law and momentary metheorological conditions. Therefore, H_{sn} is calculating by difference between the total incoming solar radiation and reflected short-wave radiation and H_{an} by difference between the total incoming atmospheric radiation and reflected atmospheric radiation.

Solar or short-wave radiation (H_s)
As the radiation penetrates the atmosphere, some of the radiation is scattered, reflected or absorbed by the atmospheric gases, clouds and dust. The amount of radiation reaching a horizontal plane is known as the solar or short-wave radiation, H_s. The net solar radiation, H_{ns}, is the fraction of the solar radiation R_s that is not reflected from the surface and is given by:

$$H_{sn} = H_s \cdot (1-\alpha) \qquad (2)$$

where (represents the albedo: the amount of solar radiation which reache the earth's surface and is reflected. The medium value of the albedo is 0.06.
If the solar radiation, H_s, is not measured, it can be calculated with the Angstrom formula which relates solar radiation to extraterrestrial radiation and relative sunshine duration:

$$H_S = R_a \cdot \left(a_S + b_S \cdot n/N\right) \qquad (3)$$

where n/N is relative sunshine duration [-] with $N = \omega_S \cdot \frac{24}{\pi}$, R_a is extraterrestrial radiation [MJ m^{-2} day^{-1}] and a_s+b_s fraction of extraterrestrial radiation reaching the earth on clear days. Where no actual solar radiation data are available, the values a_s = 0.25 and b_s = 0.50 are recommended (Rutherford et al 1993).
The extraterrestrial radiation, R_a, for each day of the year and for different latitudes can be estimated from the solar constant, the solar declination and the time of the year by:

$$R_a = \frac{24 \cdot 60}{\pi} \cdot G_{sc} \cdot d_r (\omega_S \cdot \sin\varphi \cdot \sin\delta + \cos\varphi \cdot \cos\delta \cdot \sin\omega_S) \qquad (4)$$

where extraterrestrial radiation is expressed in [$MJm^{-2}day^{-1}$], G_{sc} is solar constant = 0.0820 MJ m^{-2} min^{-1}, d_r inverse relative distance Earth-Sun, ω_s sunset hour angle [rad], φ latitude [rad] and δ solar declination [rad]. The inverse relative distance Earth-Sun, solar declination, sunset hour angle and daylight hours, are computed with the following equations:

$$d_r = 1 + 0.333 \cdot \cos\left(J \cdot 2\pi/365\right) \qquad (5)$$

$$\delta = 0.409 \cdot \sin\left(J \cdot 2\pi/365 - 1.39\right) \qquad (6)$$

$$\omega_S = \arccos(-\tan\delta \cdot \tan\delta) \qquad (7)$$

where J is the Julian day.

Atmospheric long-wave radiation (H_n):
The long-wave radiation received by the atmosphere increases its temperature and, as a consequence, the atmosphere radiates energy of its own. Consequently, the earth's surface emits (H_b) and receives (H_a) long-wave radiation (Imboden and Wust 1995). The difference between outgoing and incoming long-wave radiation is called the net long-wave radiation, H_{an}. The long-wave radiation from the surface of the body is estimate with the Stephan-Boltzman law:

$$H_a = \varepsilon_a \cdot \sigma \cdot (273 + T_a)^4 \qquad (8)$$

where ε_a is the emissivity of the air, usually estimate by empirical way, σ is the Stephan-Boltzman constant and T_a is the air temperature. For the cloudless sky the emissivity of the air depends only by the air temperature. By contrary, for the cloudy sky the emissivity of the air depend both to the air temperature and the fraction of the cloud cover by (Antenuci and Imberger 2001):

$$\varepsilon_a = 0.937 \cdot 10^{-5} \cdot \left(1 + 0.17 \cdot c^2\right)(273 + T_a)^2 \qquad (9)$$

where c is the cloudiness which can vary between 0 and 1.
The reflected long-wave atmospheric radiation can be estimated by various formulas. Usually 3% of the atmospheric radiation is assumed to be reflected (Jobson 1997). Thus, the net long-wave radiation is given by:

$$H_{an} = 5.18 \cdot 10^{-13} \cdot \left(1 + 0.17 \cdot c^2\right)(273 + T_a)^6 \qquad (10)$$

with T_a expressed in °C.
Longwave back radiation from the water surface (H_b) is expressed by Stephan-Boltzman Fourth Power Radiation law for a blackbody as (Fisher et al. 1979):

$$H_b = 5.44 \cdot 10^{-8} \cdot (273 + T_w)^4 \qquad (11)$$

where T_w is the water surface temperature expressed in °C.

Evaporative heat flux (H_e)
The heat loss to evaporation can be often important. The evaporative heat flux from the water surface can be expressed as a function of the water temperature and the wind speed in the proximity of the water surface (Lap and Inoue 2007):

$$H_e = \rho_W \cdot L_{W \cdot E} \qquad (12)$$

where ρ_w is the water density, L_w is the latent heat of vaporization and E is evaporation rate expressed by (Jobson 1997):

$$E = 3.01 + 1.13 \cdot u \cdot (e_s - e_a) \qquad (13)$$

where u is the wind speed, e_a is the vapor pressure and e_s is the saturation vapor pressure at the water surface. The saturation vapor pressure is related to air temperature and given by (Kramm and Dlugi 2011):

$$e_s = 0.6108 \cdot e^{\left(12.27 \cdot T_a / T_a + 237.3\right)} \qquad (14)$$

The actual vapor pressure can also be calculated from the relative humidity:

$$e_a = e_s \cdot Rh/100 \qquad (15)$$

where Rh is the relative humidity.

Conductive heat flux (H_c)
Heat can be transferred in both senses by conduction at the air/water boundary. The conductive heat flux is related to evaporative heat flux, through the Bowen ratio:

$$R = \frac{H_c}{H_e} = 6.19 \cdot 10^{-4} \cdot p \cdot \left| T_w - T_a / e_s - e_a \right| \qquad (16)$$

where p is atmospheric pressure.

Penetration of heat into the water column
The radiation have a penetrative component and a non-penetrative one, depending on its wavelength (Antenuci and Imberger 2001). The rate at which solar energy imparts radiative energy to the surface of the water column is a function of the net solar short-wave radiation and the remaining heat fluxes at the surface of the lake/reservoir. (Spigel et al. 1986) The short-wave radiation in a water column decay exponentially with depth *z* and is given by the Beer's Law:

$$H(z) = H^* \cdot e^{-\eta \cdot z} \qquad (17)$$

where η is a coefficient of extinction and $H^*=H_{sn}$ for the z>0 and $H^*=H_w$ for the z=0 (z counted positive when going deeper). The values of extinction coefficient depend greatly on the biological production of the aquatic ecosystem, and vary between 0.2 m^{-1} for oligotrophic ecosystem to 4.0 m^{-1} for eutrophic ecosystems (Spigel et al. 1986). The evolution of temperature in time, when the wind is neglect, is given by:

$$dT/dt = -\alpha \cdot H(z) / C_p \cdot \rho_w \qquad (18)$$

where α is the thermal coefficient of expansion of the water.

RESULTS AND DISCUSSION

The meteorological elements that significantly affect lake thermal regimes and heat storage include air temperature, wind and net radiation. Unfortunately, in practice there are many situation when these data are not available. In this paper is investigated the consistency of a model which simulates the radiation fluxes variation on a lake surface and the influences on lake's water temperature. The model allow to estimate the energetic budget due to solar radiation on aquatic ecosystem, based on its geographical position only. Thus, the model first asses the rising and the setting time for Greenwich Time and local time (Figure 1). We can see that the model predictions are quite good.
Secondly, daily extraterrestrial radiation is determined and the component radiation of the total flux at the level of the studied aquatic ecosystem is computed (Figure 2). The total heat flux variation on lake surface varies less on seasonal scale than on dayly scale. The total thermal minimum flux coincides with the minimum of solar radiation, while the thermal maximum flux is reached much sooner than maximum of solar radiation.

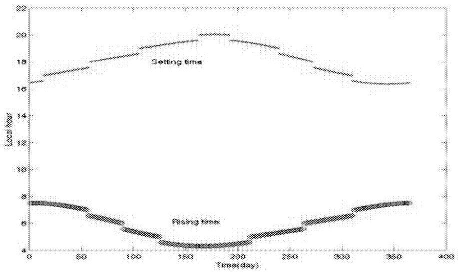


Figure 1. Rising and setting time for the Golesti reservoir

Throughout the spring and summer the sensible heat flux H_c is often directed towards the lake surface.Once cooling begins, Hc is consistently positive due to unstable atmospheric conditions. Since the total thermal flux H_w is the results of interactions between the athmosphere and the lake, it directly influences the water temperature. Thus, for positive values of H_w, the water temperature will increase.

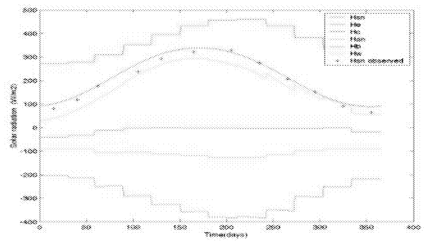


Figure 2. Yearly energy balance for Golesti reservoir

Thirdly, the water column temperature variation over the year is computed. The behavior of the water column temperature is shown in Figure 3.

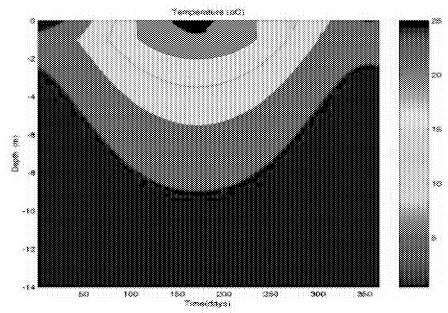


Figure 3. Temperature variation over the year in Golesti reservoir

Golesti reservoir is dimictic and undergo spring and autumn vertical overturning and summer thermal stratiphication. The lake surface temperature increased in March when the net energy flux is positive. The thermocline is very well established in June when heat was received at a higher rate than the rate of transfer to deeper layers and the thermocline depth increased rapidly.

CONCLUSION

A numerical model for a sezonier mixed layer is presented, based on the one-dimensional equations for conservation of thermal energy. The model was tested over one year using field data from Golesti reservoir – Romania. The simulated isotherms demonstrate the strong degree of temperature stratiphication induced by solar radiation. The Golesti lake was a least partially stratified for nine mounths of year.The case study presented in this research provided a good opportunity for testing the model. All the results of the simulation have a good fit with the observed data.

FURTHER RESEARCH

The lack of consistent weather and water quality data led us to propose a model to simulate the energetic behavior of lakes. Further on the model must be develop in order to quantify the wind energy and to be embedded into a complex water quality model.

ACKNOWLEDGEMENT

The work has been co-funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Romanian Ministry of Labour, Family and Social Protection through the Financial Agreement POSDRU/89/1.5/S/62557.

REFERENCES

Atenucci J.P. and J. Imberger,. 2001. “ Energetics of long internal gravity waves in large lakes”, Limnology and Oceanography, Vol. 46(7), 1760-1773.

Charuchittipan D. and J.D. Wilson. 2009. “Turbulent kinetic energy dissipation in the surface layer”. Boundary Layer Meteorology, Vol. 132, 193-204.

Jobson H. E.. 1997. “ Enhancements to the Branched Lagrangian Transport Modeling System, U.S. GEOLOGICAL SURVEY Water-Resources Investigations Report 97-4050, Reston Virginia.

Fischer H.B., E.J. List, R.C.Y. Imberger and N.H. Brooks. 1979. “Mixing in inland and costal waters” New York, Academic Press, 483 p.

Imberger J. and J.C. Patterson,. 1990. “Physical Lymnology” In Advances in Applied Mechanics, T. Wu, Ed. Academic Press, Boston, 27, 303-475.

Imboden D.M. and A. Wust. 1995. “Mixing Mechanisms in lakes”. In Physic and Chemistry of Lakes, eds. A. Lerhman, D. Imboden, J. Gat, 2nd ed, Springer-Verlag, New Yorg Inc, USA, 63-82.

Kramm G. and R. Dlugi, 2011. “Scrutinizing the atmospheric greenhouse effect and its climatic impact”, Natural Science, Vol. 3, 971-998

Lap B.Q., K. Mori and E. Inoue. 2007. “A one-dimensional model for water quality simulation in medium- and small-size rivers”, Paddy Water Environmental, Vol. 5, 5-13.

Oswald C. J. and R.W. Rouse. 2004. “ Thermal characteristics and energy balance of various-size Canadian Shield Lakes in the Mackenzie River Basin”, Journal of hydrometeorology, Vol. 5, 129-144.

Rutherford J. C., J. B. Macaskill, and B. L. Williams . 1993. “Natural water temperature variations in the lower Waikato River, New Zealand, New Zealand”, Journal of Marine and Freshwater Research, 27:1, 71-85.

Spigel R.H., J. Imberger and K. N. Rayner. 1986. “Modeling the diurnal mixed layer”, Limnology and Oceanography, Vol. 31(3), 533-556.

BIOGRAPHY

Gabriela Elena Dumitran was born in Romania on the 11th of June, 1972. She received the PhD degree in power engineering from the University POLITEHNICA of Bucharest, in 2002. She is currently a Lecturer in the Hydraulics, Hydraulic Machinery and Environmental Engineering Department from the University POLITEHNICA of Bucharest.

AUTHOR LISTING

AUTHOR LISTING