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ECEC'2014

10TH FUTURE BUSINESS TECHNOLOGY CONFERENCE

FUBUTEC'2014

EDITED BY

Nicolae Vasiliu

and

Jeanne Schreurs

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10TH FUTURE BUSINESS TECHNOLOGY CONFERENCE

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Preface

It is our great pleasure to welcome you at the Novotel, in the beautiful city of Bruges, Belgium, for our annual European Concurrent Engineering Conference (ECEC 2014), the FUture BUsiness TEChnology Conference (FUBUTEC 2014) and EUROMEDIA'2014, which are held from April 28th-30th, 2014, and supported by the POLITEHNICA University of Bucharest.

The accepted presentations for the conferences cover E-Learning Environments, Project Planning, Concurrent Engineering Design and Concurrent Engineering in Energy Applications. The presentations provide an open forum for researchers from academia and other research communities to present, discuss and exchange related ideas, results, and experiences in these areas.

For the benefit of the participants and authors, we have endeavoured also to make the event an interesting one by inviting a number of high-level speakers to expand upon their research for the general benefit of all those present.

The keynote talks are by Ioan Dumitrache, of the Romanian Academy of Sciences, University "Politehnica"of Bucharest, Bucharest, Romania, who will talk on "Cyber-Physical Systems - new challenges for Science, Technology and Education", by Seyed M. Mussavi Rizi, of Scensei, Zurich, Switzerland who will talk on "The not so happily ever after - On the use and usefulness of social simulations" and invited talks by Hans Degraeuwe of Degraeuwe Consulting NV, Belgium who will talk on "Modular SkyScrapers for MegaCities" and by Joeri Van Dooren, WeePee NV, Belgium.

As we commemorate in 2014 the First World War, all conference participants are invited on the 30th of April to visit the medieval city of Ypres which was the scene of some major WWI battles and now hosts the world famous "In Flanders' Fields Museum" offering the visitor a multimedia experience of the First World War. Next to the museum we will let you discover the Ypres city museum, the city itself and its surroundings.

We would like to thank all the authors for submitting their research work within the conferences, as well as to the authors of accepted papers for their participation and presentation of the papers during this year's event.

Furthermore, we also hope you have some free time after the conferences to enjoy the beautiful city of Bruges and its surroundings.

We look forward to meet you all again in Lisbon in April 2015 for next year's edition of the conferences!

Nicolae Vasiliu
Jeanne Schreurs
And
Philippe Geril

FUBUTEC-ECEC-EUROMEDIA'2014
Conference Chairs

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SCIENTIFIC PROGRAMME

E-LEARNING ENVIRONMENTS

TELLING THE STORY: AN INTERACTIVE MULTIMEDIA EXHIBIT NARRATING THE 900 YEARS OF THE ALMA MATER

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KEYWORDS
Digital Storytelling, Alma Mater Studiorum, Bologna City Museum, Genus Bononiae, Multimedia Design, Digital Space Interaction, Aesthetics, Saul Bass.

ABSTRACT
In this paper we present the steps that led from the conceptualization to the implementation of an interactive multimedia storytelling system that narrates the history of the Alma Mater Studiorum, University of Bologna. The aim of this work has been that of providing the Bologna City Museum (based in the Pepoli Palace and run by Genus Bononiae) with a system that describes the almost millenary history of the University of Bologna. In fact, the history of the Alma Mater was incredibly missing inside this Museum. Hence a small, but heterogeneous group of professionals, which includes historians, computer scientists, artists, art directors, 3D animators and academics, undertook this complex task, considering the important background of the institution, which boasts a history that includes the affiliation of characters that range from Dante Alighieri (the author of the Divine Comedy) to Giosue' Carducci (the first Italian Nobel prize laureate for literature). The outcome of this work is that the Alma Mater has regained the center of the stage, inside the main city museum of Bologna, with the use of modern digital storytelling techniques and following rigorous aesthetic principles, all put to good use to finally let visitors easily browse through the highest historical moments of such institution.

INTRODUCTION
This is an incredibly vibrant moment for many museums and cultural institutions all over the world, as digital technologies such as the Internet and modern human computer interaction techniques have provided many of such venues with a direct channel with the public, channel that once was absolutely unavailable. It is hence today possible to find a common ground of understanding with all tech-familiar people, which exceeds in all forms those that were available before, and that helps creating a link, some call it virtual, others direct, between visitors and museum exhibits. Such type of communication has clearly begun with the creation of web portals and the digitalization (e.g., pictures, 3D scans, etc.) of museum exhibits, but has slowly grown to include an emerging consciousness of such institutions which are not anymore limited today to a role of memory preservation venues, but now also often play the role of places where innovation and breathtaking experiences can be lived. All this is now possible because technologies have clearly changed the ways and the pace at which we all communicate and approach reality. In essence, technology is no longer a matter limited to discussions between experts on communication protocols and codecs (Marfia and Roccetti 2010). In particular, technology often acts as an intermediary that puts a person in communication with reality. Museums, on their side, have not seen themselves spared from this process, also their information, their rich history and great stories often become today more comprehensible the moment they are interpreted, understood, i.e., seen, through the eyes of a digital system (Roccetti et al. 2010, Roccetti et al. 2012). While what should be the correct degree of pervasiveness of digital technologies in cultural institutions is a matter under study, often object of controversial debates, something that is today unconfutable is that the use of digital technologies is highly requested in all cultural venues, anywhere placed in the world. Why this is happening we have already said, but we can further summarize in one phrase: technology is the *intermediary*, the lens, through which many people today deal with reality. Getting to the practical aspect of this idea, it is through some type of digital device that people today judge and let the rest of the world know about their tastes (be it a trip, a restaurant, etc.), influence politics (e.g., consider the importance of blogs and tweets in many facts happening in the political arena) or, more simply, find the nearest gas station. Such revolution is hence understood and acknowledged by many cultural institutions around the world, which in different ways, provide novel means of understanding and discovering their artwork through technology. As an example, consider the recently renovated Cleveland Museum of Art that revealed its brand new exhibit, the Collection Wall, *the largest multi-touch screen in the United States—a 40-foot, interactive, micro tile wall featuring over 3500 works of art from the permanent collection, most of which are on view in the galleries an entire wall occupied by touchscreens* (www.clevelandart.org 2014). Interestingly, within the Cleveland Museum, its curators did not only try to place an interesting piece of technology as an aid to normal institutional operations (e.g., digital guide, etc.), they also sought for an artistic way of placing technology itself inside the museum. In this work, we can hence find that technology does not only play as a bridge that connects a visitor to the deep cultural and aesthetic meaning of an exhibit, technology itself becomes part of the exhibit, not only for how it works, but also for how it looks. This is a second interesting trend, as aesthetics and technology are more and more seen as key factors for capturing attention and improving usability, also in museums contexts as we will shortly describe (Tractinsky 1997, Ahmed et al. 2009). In this interesting evolving trend, where technology, aesthetics

and so-called traditional culture blend, combining one with the other in different forms and ways, we will here describe the conceptualization and the implementation of an interactive multimedia storytelling system that well falls along these lines. Taking one step back, at the beginning of 2013 the curators of one of the major museums of the Bologna City Museum, based in the ancient Palazzo Pepoli and run by a public institution termed Genus Boniae, decided that time had come to dedicate an area to the rich history of the local University. In fact, the University of Bologna is widely recognized as the oldest one in the western world. For this reason, although the Palazzo Pepoli Museum is brand new and has been only very recently opened, i.e., on January 28th 2012, this museum has immediately appeared incomplete, as no room inside this museum was specifically devoted to the University. Such gap has been filled on the past January 24th 2014. In this paper we describe how and by which means. The remainder of this paper is organized as follows. In the *Context* Section we will describe where the team started from and how the right location for the history of the University has been found. In the *Concept* Section, instead, we will discuss which are the fundamental choices that have been made (aesthetic, historical, artistic), while in the *Implementation* Section we briefly anticipate details about the implementation of the system.

CONTEXT

The context within which our team has moved to find the ideal staging of the history of the University is the Bologna City Museum in Palazzo Pepoli. This is a remarkable construction, whose history begins in 1276 when Romeo Pepoli, one of the Pepoli family members, acquires real estate property in the city of Bologna to settle down his business headquarters. Its location right at the city center and the wealth of its owners let this building become one of the most prestigious of Bologna. Many centuries later, in 2004, the palace's ownership was transferred to a public foundation, the Fondazione Carisbo, with the scope of creating the city museum of Bologna. Since 2004 the building has undergone considerable renovations and, although it has not been modified in its structure, it has been augmented with a brand new heart. In fact, the center of thepalace, originally occupied by a very spacious courtyard, has been partially filled with a new infrastructure, consisting in a steel and glass tower, which no one would expect to find in such type of setting. The architect, *Mario Bellini* (http://en.wikipedia.org/wiki/Mario_Bellini) with his creation points to new ways of experiencing culture, ways where attention is posed on the preservation of both the container and its content (http://it.detail-online.com 2014, http://www.genusbononiae.com 2014). Now, the brand new glass and steel tower, which metaphorically represents the content, i.e. the history of Bologna, offers the possibility of staging exhibits and artifacts along its rooms and halls. Interestingly, this has been identified being the best place, both for its significance and for its practical position, for Bologna's most important jewel, the story of how within the walls of its University fundamental pieces of knowledge have been constructed by the hard work of generations of students, scholars and scientists.

CONCEPT

Glass and steel, two very simple materials that have been combined so well in so many different institutions and monuments around the world, hence amounted to the substrate upon which the new installation would lie. Clearly, such type of staging immediately suggested that any new exhibit representing the University should occupy the minimal required space, in order to properly well integrate with the surrounding space. However, minimalism, or simplicity, was not only imposed by the particular context, it was also imposed by the history of the University itself. In fact, the task of portraying a so long history, made of so many keystone moments, ideals and human stories, required a drastic simplification process, as we were here realizing a celebrative installation, not an encyclopedic one.

We ended finding out that minimalism, hence, was not only an aesthetic constraint, but also a user experience one (De Angeli et al. 2006, Hartmann et al. 2007, Resnick et al. 2000, Rosner et al. 2014). Keeping this idea in mind, we moved along two different directions, creating, hence, two distinct digital storytelling systems. The first direction entailed providing a visitor with the idea of the two fundamental historical events that occurred in Bologna: (a) the crowning of Emperor Charles V, and, (b) the signature of the Magna Charta Universitatum, the fundamental document that renovates university traditions and bonds, by all University Rectors from all around the world. The second direction, instead, amounted to identify the distinctive symbols, i.e., events and notable people that best represent the long history of the University. For what concerns the first part of the installation, the one that represents the crowning of Emperor Charles V and the signature of the Magna Charta, the choice has been that of portraying the two processions that occurred during these two events. For this reason, the skillset of a very well known Italian artist, Giuseppe Palumbo, was engaged. (http://it.wikipedia.org/wiki/Giuseppe_Palumbo_(fumettista)

Thanks to Mr. Palumbo's work and to the work of a skilled group of 3D animation experts it has been possible to recreate the myth of the two processions using the language of computer 3D motion comics. For what concerns, instead, the second part, after everlasting discussions, which considered both the historical and the scientific aspects of the choices that were being made, sixteen of such symbols were identified. However, identifying such symbols was not enough. It was also important to find a way of putting such symbols, often completely unrelated, if not for the common Bolognese roots, together. The creativity of *Saul Bass* provided that aid, so deeply necessary at this point (Bass 1959, Bass 1960). In fact, just as Saul Bass masterfully did with film titles, creating connections with different objects, people, titles, that would incredibly morph one into the other, while still preserving the semantics of the underlying story, we here wove the thread of the University's history through sixteen different stories. In Figure 1 through 16 we provide those storyboard parts that specifically relate to the given symbols: Mosaic Tile, Moonstone, Empire Symbol, Student, Scalpel, Squared Note, Third Degree Equation, Blazon, Gregorian Calendar, Leaf, Prims, Frog, Poggi Palace, Carducci, Globe, University of Bologna Symbol. Now, what we would like to emphasize in the choice that has been made

by the involved historians, artists and artistic directors, is that all these symbols seem to be extremely generic.

However, each of these extremely generic symbols is closely related to a given phase of the University. For example, the leaf symbol recalls the fact that during Renaissance, a new awareness pervaded the investigation of the great book of nature. Classification, in that period, became the method utilized by naturalists; botanical gardens were perhaps the first laboratories. All this is very important in the University's growth, as Bologna's *Ulisse Aldrovandi* was unmatched in this science (http://en.wikipedia.org/wiki/Ulisse_Aldrovandi).

A second interesting example is given by the third degree equation symbol. In fact, Scipione del Ferro, a Renaissance mathematician that taught at the University of Bologna, first discovered a method to unlock its solutions (http://en.wikipedia.org/wiki/Scipione_del_Ferro).

As a last example, let us consider the frog sketched in Figure 12. While in Bologna, Luigi Galvani, a physician, ignited the first sparks of a whole new science, bioelectricity, while experimenting with the dead bodies of frogs (http://en.wikipedia.org/wiki/Luigi_Galvani).

In essence, the driving ideal that has led to the creation of the installation that represents the University of Bologna in Palazzo Pepoli is that of representing the main historic symbols that best portray it. This is not all, however. In fact, inspired by what Saul Bass has taught in his professional carreer, we have narrated a multimedia story where any given symbol becomes subjected to a graphical transformation thus to morph itself, after a few tens of seconds since its first appeareance, into the subsequent new symbol in the story. This way, a sequence of graphical symbol transformations account for the historical centenarian transformations that have contributed to the fame of the University of Bologna. In the next Section we will briefly unveil additional details on how all this has been implemented.

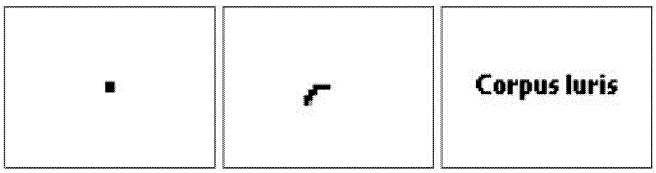


Fig. 1: Mosaic Tile.

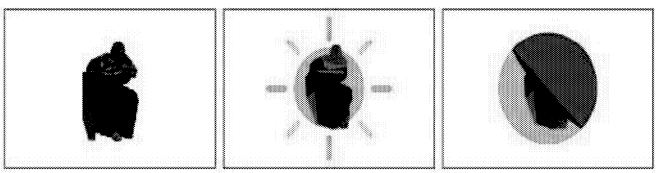


Fig. 2: Moonstone.

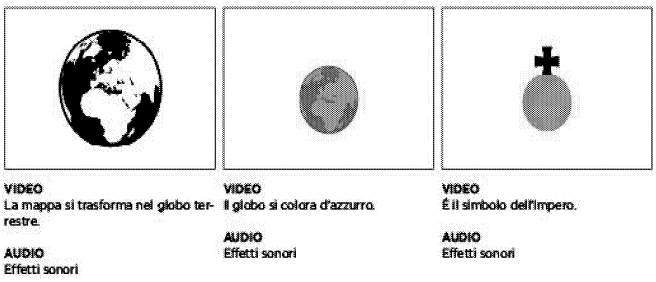


Fig. 3: Empire Symbol.

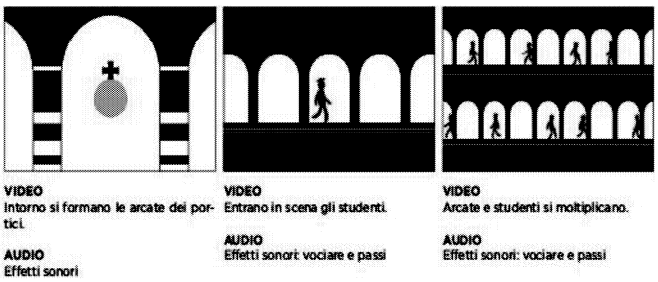


Fig. 4: Student.

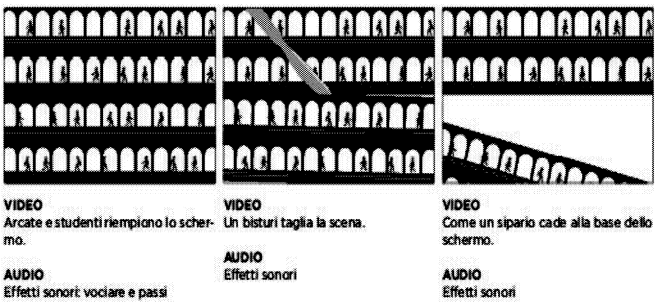


Fig. 5: Scalpel.

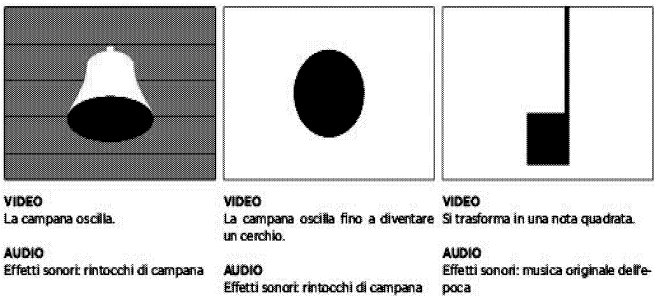
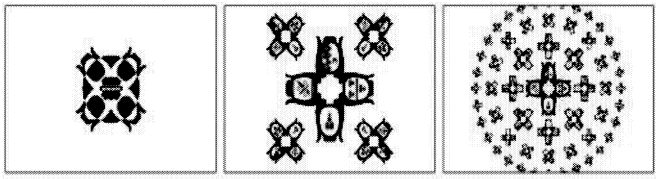


Fig. 6: Squared Note.



Fig. 7: Third Degree Equation.



VIDEO
La formula si dissolve e resta lo stemma.

AUDIO
Effetti sonori

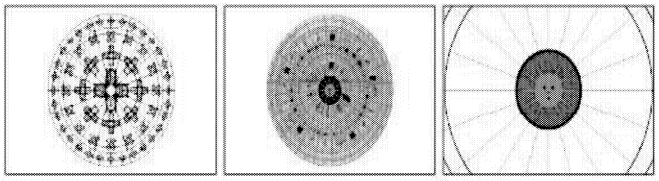
VIDEO
Gli stemmi si moltiplicano: sono quelli del complesso araldico delle Nationes degli studenti.

AUDIO
Effetti sonori

VIDEO
Gli stemmi ruotano in un caleidoscopio di colori.

AUDIO
Effetti sonori: musica originale dell'epoca

Fig. 8: Historical Blazon.



VIDEO
Gli stemmi si trasformano nel calendario gregoriano.

AUDIO
Effetti sonori: musica originale dell'epoca

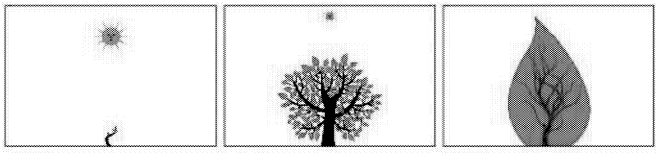
VIDEO
Il calendario ruota nello schermo.

AUDIO
Effetti sonori: musica originale dell'epoca

VIDEO
Al suo centro un sole sempre più luminoso.

AUDIO
Effetti sonori: musica originale dell'epoca

Fig. 9: Gregorian Calendar.



VIDEO
Il sole brilla in alto sullo schermo e fa crescere una pianta.

AUDIO
Effetti sonori

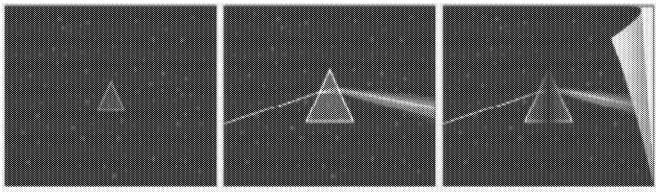
VIDEO
La pianta cresce rigogliosa.

AUDIO
Effetti sonori

VIDEO
Vediamo nel dettaglio una foglia con le venature.

AUDIO
Effetti sonori

Fig. 10: Leaf.



VIDEO
Nella notte stellata appare un prisma.

AUDIO
Effetti sonori

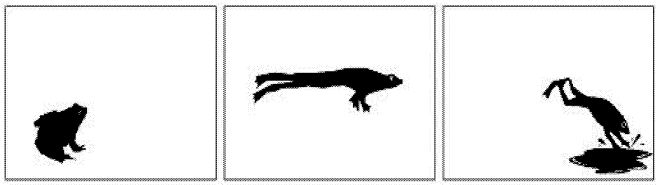
VIDEO
Fasci di luce entrano nel prisma rifrangendosi.

AUDIO
Effetti sonori

VIDEO
Lo schermo si sfoglia come la pagina di un libro.

AUDIO
Effetti sonori

Fig. 11: Prism.



VIDEO
La saetta da vita a una piccola rana.

AUDIO
Effetti sonori: rumore di gracidare

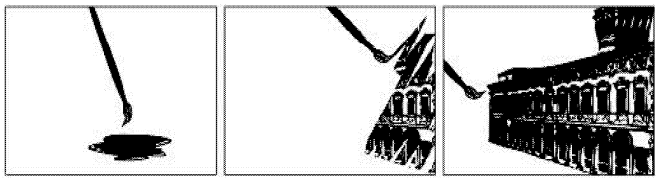
VIDEO
La rana attraversa lo schermo saltellando.

AUDIO
Effetti sonori: rumore di gracidare

VIDEO
Sull'ultimo saltello si tuffa in una macchia d'inchiostro.

AUDIO
Effetti sonori

Fig. 12: Frog.



VIDEO
Entra in scena un pennello che s'intinge nell'inchiostro.

AUDIO
Effetti sonori

VIDEO
Il pennello inizia a dipingere un palazzo.

AUDIO
Effetti sonori

VIDEO
È Palazzo Poggi.

AUDIO
Effetti sonori

Fig. 13: Poggi Palace.



VIDEO
Le onde si trasformano in parole.

AUDIO
Effetti sonori: voce che declama

VIDEO
È il discorso di Giosuè Carducci per le celebrazioni dell'ottavo centenario dell'Università.

AUDIO
Effetti sonori: voce che declama

VIDEO
All'interno di una lettera, ecco il ritratto di Carducci.

AUDIO
Effetti sonori

Fig. 14: Carducci.



VIDEO
Intorno al ritratto si formano le due date dell'ottavo e del nono centenario.

AUDIO
Effetti sonori

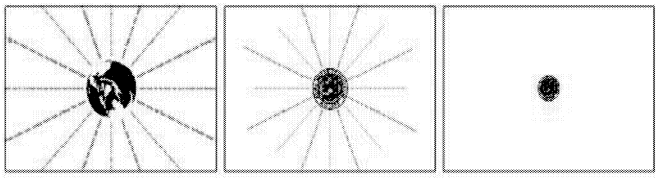
VIDEO
Ruotando intorno al ritratto lo trasformano in un globo.

AUDIO
Effetti sonori

VIDEO
Il globo emana i nomi dei paesi firmatari della Magna Charta.

AUDIO
Effetti sonori

Fig. 15: Globe.



VIDEO
I nomi come dei raggi si allontanano dal globo che si rimpicciolisce.

AUDIO
Effetti sonori

VIDEO
Il globo inizia a trasformarsi.

AUDIO
Effetti sonori

VIDEO
È il logo di Unibo.

AUDIO
Effetti sonori

Fig. 16: University of Bologna Symbol.

SOME FEW IMPLEMENTATION DETAILS

Once the two directions of work have been identified, the problem became that of understanding which could be the best ways of implementing them. Truly believing to the adage "one picture is worth a thousand words", we show how the installation appears to a visitor in Palazzo Pepoli in Figure 17. In particular, it is possible to see that the underlying glass and steel infrastructure has not been changed in any way and that the installation, composed of two video walls perpendicular to each other and of a totem placed at the middle of the room well fits with the surrounding architectural features.

The two video walls have been placed perpendicularly one to the other, as they are in this way capable of giving a visitor the illusion of a 3D setting. Such effect is implemented letting the processions that occurred when Charles V was

crowned, as well as when the Magna Charta was signed, move from one video wall to the other. When standing at the center of the room, hence, a visitor can feel right as if s/he were at the center of P.zza Maggiore, the main city square. A completely different experience is instead available at the video totem, placed at the center of the room. Also this piece of the installation has been thought in a way that it could well blend with the architectural that lie around it. The totem is, hence, in glass and the screen it embraces readily captures attention. How the application running on the touchscreen appears is shown in Figure 18. While a video runs, narrating through subsequential graphical transformations the story sketched by the sixteen symbols described in the previous Section, a copy of all symbols sit at the bottom of the screen, along with a timeline that marks the centuries that correspond to the given event appearing on the screen. As the video runs and specific symbols appears (after a graphical transformation), the corresponding symbols sitting at the bottom of the screen lights up. This indicates that that symbol is now active and that, if the visitor touches it, the video will pause and it will be possible to read the caption of the given symbol on a pop-up window. Clearly, the best way of enjoying the performance is visiting the museum.



Fig. 17: Global view.

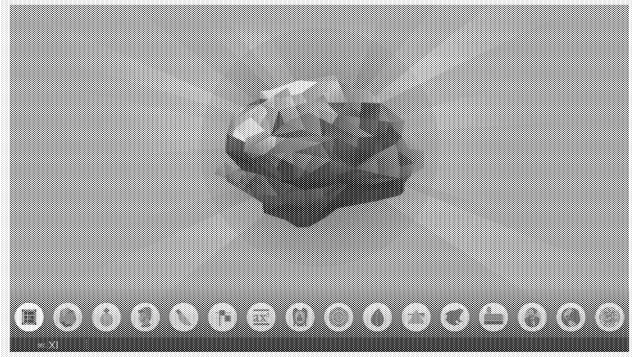


Fig. 18: Touchscreen.

CONCLUSION

We here briefly described how a very broad concept, i.e., describe the history of the University of Bologna, has been concretized into the actual implementation of a performance system exhibited at the City Museum of Bologna in Palazzo Pepoli.

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ONLINE TUTOR-STUDENT INTERACTION COULD COMPENSATE THE LACK OF MOTIVATIONAL EFFECTS THAT CHARACTERIZE FACE-TO-FACE LEARNING

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KEYWORDS
E-technology, E-Learning, Tutor-Student Online Interaction, Learning Management System (LMS).

ABSTRACT

It is well known that students in a blended-learning system (a hybrid learning system that facilitates the use of E-learning tools as a complementary resource to face-to-face lectures) have less opportunity to personally interact with their tutors. We studied this issue by considering the relative effect of tutors' online behavior on students' overall performance by using the Learning Management System (LMS) of the Arab Open University in Kuwait. We found a considerable discrepancy in the way and amount of time tutors interacted online with their students. Not only the frequency of using the LMS by students was affected in response to tutors' online activity, but also students' overall performance in the corresponding courses. A linear correlation between tutor's online activity and students' overall performance in the corresponding courses suggests that the frequent use of the LMS by tutors could compensate the lack of motivational effects that may otherwise proliferate through face-to-face interactions between tutors and students in the traditional learning system. These findings imply that as tutoring in higher educational institutions shifts from pure face-to-face lectures to embedding E-learning components, tutors should correspondingly shift their behavioral répertoire to increasingly depend on the LMS when interacting with their students.

INTRODUCTION

It is widely accepted among educational researchers that a dialogue-based instructing is more effective than a monologue-based one (Desmarais and Baker, 2012). In what became to be known as the two sigma effect, Bloom (1984) showed that participants of a dialogue-based learning scored two standard deviations higher than monologue-based learners (Anderson et al., 1994). Further research confirmed the objective quality of the two sigma effect irrespective of tutors' expertise (Cohen et al., 1982).

On the other hand, research on students' performance in a blended-learning system identified three main categories of influences (Lim and Morris, 2009). Some refer to students themselves, in terms of individual differences, others concern the course delivery, and the third category deals with students' motivations.

It is well known that students in a blended-learning environment have less opportunity to interact with their tutors face-to-face. This calls for additional efforts on the side of both tutors and students. For example, a student may still need the help of the tutor despite having tried alone to understand the delivered material. The problem becomes more complicated if the failing material constitutes a prerequisite for further materials.

The current work focuses on two points. Specifically, we investigate whether the use of the Learning Management System (LMS) imposes different conditons on its users (tutors and students) and whether the interaction between tutors and their students affects the performance of the students. We quantify students' performance as the ratio of the number of students who successfully completed a course to the total number of the course attendees. Tutors' LMS contribution to students' performance is quantified as the ratio of the total time a tutor spent on the LMS to the number of students she/he had during the period of data collecting.

Finally, we present results that pave the way for further interesting hypotheses, e.g. which categories of students, in terms of grade scale, benefit most from tutors' LMS interaction between students and tutors.

METHODS

To investigate the role of tutors' online activity on students' performance within blended-learning environments, we analyzed data gathered through the Learning Management System (LMS) of the Arab Open University during the period from February 15th to May 15th, 2013. Table 1 shows our organizing of the data.

Data

We compared two sets of data: one preserves tutors' LMS activity and the other corresponds to students grades after they have completed their courses. Specifically, records of data demonstrating tutors' LMS activity were collected for tutors from the Faculty of Computer Studies (referred to by the numeric value 1 in column 1 of Tab. 1), the Faculty of English Studies (value 2 in column 1 of Tab. 1) and the Faculty of Business Studies (value 3 in column 1 of Tab. 1) at the Arab Open University – Kuwait Branch. A single

record contained the total number of sections and students the tutor had, the number of LMS hits she/he did, the number of messages she/he sent to and received from her/his students and the amount of time (in minutes) she/he spent on the LMS within the three months period of collecting the data.
Data corresponding to students' performance were available *only* for certain courses. This reduced the size of the investigated sample to a total of 26 tutors distributed over the three faculties as follows: 9 tutors from the Faculty of Computer Studies, 10 tutors from the Faculty of English Studies and the remaining 7 tutors belonged to the Faculty of Business.

Table 1: Organizing the Data

Tutor	Dept.	Pass %	ADAT (min/std)
1	1	55	3.96
2	1	59	1.60
3	1	77	1.66
4	1	51	1.16
5	1	63	1.90
6	1	71	3.50
7	1	30	1.35
8	1	43	0.46
9	1	52	0.47
10	2	79	0.00
11	2	93	1.22
12	2	81	0.27
13	2	82	0.74
14	2	68	0.08
15	2	88	0.00
16	2	83	0.41
17	2	85	0.46
18	2	82	11.55
19	2	79	2.16
20	3	58	4.45
21	3	64	0.01
22	3	63	0.37
23	3	65	0.61
24	3	69	1.98
25	3	47	0.94
26	3	65	1.49

Measuring Tutor's LMS Potential Contribution to Students' Performance

The limited number of courses to which students' grades were available restricted the analysis to lesser students than could have been, otherwise, had the full capacity of students' number been deployed for each tutor. However, assuming an evenly tutor-student interaction, we compensated the failing in students' numbers by averaging the time each tutor spent on the LMS over the total number of her students during the period of data collecting. In so doing, a new measure resulted that described the **A**verage **D**uration of a **T**utor's LMS **A**ctivity (ADTA), expressed in minutes per student (column 4 of Tab. 1).
For example, during the time of data collecting, tutor 1 from the Faculty of Computer Studies had 9 sections with a total of 183 students. She spent 725 minutes on the LMS, ranging from posting learning materials to interacting with her students (reading and replying to messages). However, since the students' grades we have for tutor 1 refer to only 6 sections (with no more than 118 students), we consider the number of minutes that tutor 1 potentially assigns to each of her students by dividing 725 by 183. The resulting value, 3.96, describes then tutor's 1 LMS contribution to the performance of every one of her students. This way, we can compare LMS contributions of the various tutors regardless the number of students they have whether due to missing sections in the course grades data or differences in the teaching loads.

Measuring Students' Performance

Students' performance was measured in terms of the number of students who passed the course in question relative to the total number of course attendees. For example, of the 118 students tutor 1 had during the period of data collecting, 53 couldn't successfully complete their courses. As a result, performance of the students taught by tutor 1 during the time interval of data collecting is 1-(53/118) or 55%. Column 3 of Tab. 1 lists students' performances for the 26 tutors that made up the sample.

RESULTS AND DISCUSSION

Concerning the point of tutors' use of the LMS, our analysis shows that different tutors used the LMS quite differently. In average, tutors belonging to the Faculty of Computer Studies sent 69 messages over the LMS to each student and received 8 messages per student. The figures were 4 messages from tutors and 164 from students compared with 43 and 5 messages, respectively, for the Faculties of English Studies and Business Studies.
To show the effect of tutors' LMS activity on students' performance, we calculated regression correlations between the ADTA and students' performance for each faculty by:

$$r_{ij} = \frac{Cov(x,y)}{\sqrt{Var(x).Var(y)}}$$

Table 2 summarizes the calculated values.

Table 2: Correlation Values

Faculty	*r*	*p*
Computer	0.42	0.25
English	0.02	0.95
Business	-0.14	0.77

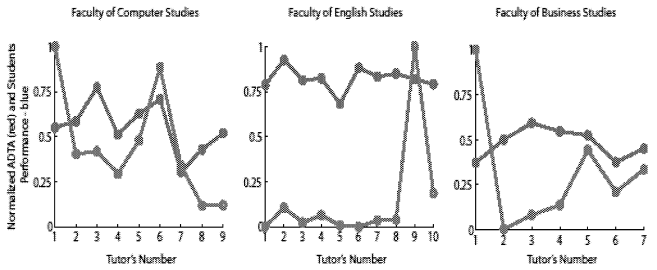


Figure 1: Plots showing normalized average duration of tutors' LMS activity (red) and the corresponding students' performance (blue).

Regarding whether the LMS imposes different conditions on its users, we grew contemplative through observing the discrepancies in the frequency of using the LMS across the faculties. Especially, members of the Faculty of English Studies showed a modest tendency to use the LMS (Tab. 2). Meanwhile, their students achieved the highest scores (Fig. 1). In terms of a hypothesized correlation between the tutor-student LMS interaction and students' performance, this would be a paradoxical result. In particular, in the absence of frequent face-to-face interactions that is adherent to traditional learning. However, to be able to hold our ground, we prefer to enlarge the test sample and expose the data to further analysis.

Yet apart from alleged paradoxes, the above observation sheds light on the role of motivation in e-learning. This includes both intrinsic and extrinsic motivation (Keung, 2012; Litman, 2005). Specifically, not only persons with backgrounds in E-technology should be capable of using the E-media. Rather, E-learning provides an opportunity to improve learners' chances in participating in education (Maguire and Zhang, 2007). In case of members of the Faculty of English, it means tutors should get themselves motivated and motivate their students to effectively use the LMS.

As to the second issue, i.e., the role of tutors' LMS activity on students' performance, only in case of the Faculty of Computer Studies could the data show a positive tendency. The *p*-value in table 2 could not provide statistical significance. However, we think of our results in terms of type II error (false negatives). Accordingly, a larger sample would only provide the statistical significance, confirming the tendency we see in Fig. 1 (first plot).

Interestingly, when running the statistical check, considering this time only students who completed their courses with grades between C and B, the correlation increases from 0.42 to 0.49 with lesser probability to get a correlation as large as the observed value by random chance, when there is effectively no correlation. In this case, the probability decreases from 25% to 18%. This raises another question that should be investigated in further studies, namely, for which students' categories within the grade scale is tutors' LMS-activity especially beneficial? Here, too, preserve this question for further investigations.

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BIOGRAPHY

OUSSAMA H. HAMID received in 2011 a Ph.D. degree in Natural Sciences (Neuroscience) from the University of Magdeburg, Germany. The title of his doctoral thesis was: "On the Role of Temporal Context in Human Reinforcement Learning". Before, he was awarded a Master's degree in Computational Visualistics (Germany, 2002) and Bachelor degrees in Computer Science (Germany, 2000) and Mathematics (Germany, 1998). In the years between 2003 and 2014, Dr. Hamid has been investigating both theoretical and practical aspects of Human-Machine-Interaction, Neural Network Functions and Cognitive Systems. Dr. Hamid has published his research findings in several European and international refereed journals and conferences.

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LEARNING, UPDATING AND SEMANTIC FUZZY RETRIEVAL OF A LEARNER PROFILE IN AN E-LEARNING ENVIRONMENT

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KEYWORDS
E-Learning, Semantic Web, Learner Profile, Ontology, Fuzzy Semantic Retrieval.

ABSTRACT

E-Learning is the use of technology to enable people to learn anytime and anywhere. E-Learning depends on learner profile for the retrieval of relevant learning content to the learner. Learner profile describes the way in which a student learns best. It includes information on learner's knowledge, interest, learning preferences and styles, goals, background etc. One of the main issues in constructing learner profile is semantic web. Ontology is used as a standard knowledge representation for the semantic web.This paper suggests an approach to construct ontology based learner profile including static and dynamic characteristics of the learner and update it automatically. Finally an efficient fuzzy semantic retrieval process is proposed for the efficient retrieval of information from learner profile.

INTRODUCTION

Comparing with the traditional face-to-face style teaching and learning, E-Learning is indeed a revolutionary way to provide education in life long term. Nowadays, E-Learning systems are widely used for education and training in universities and companies because of their electronic course content access and virtual classroom participation. Due to the rapid increase of learning content on web, it is time consuming for learners to find content what they really want to and need to study. Without knowing anything about the learner, a system would perform in exactly the same way for all learners. The success of any E-Learning system depends on the retrieval of relevant learning contents according to the requirement and understanding ability of the Learner.

In order to satisfy the requirements of the learner, learner profile is needed to reflect the true learner needs. Learner profile is a structure containing information both directly and indirectly pertaining to user's preferences, behaviour and context. It represents learner's interest as well as information and knowledge about domain that is relevant for a Learner. Learner profiles can form a good representation of the learning context, which promises to enhance the usage of learning content. It is a necessary factor for building an effective and accurate adaptive system. One of the main issues to take into account in the process of constructing learner profiles is the notions of the Semantic Web. Semantic Web relies heavily on formal ontologies to structure data for comprehensive and transportable machine understanding. The ontological representation of the user profile enhances the performance in tasks such as filtering, information retrieval, classification, information management etc.

Various research studies were encountered in the process of creation of user profile. User profile can be created from both static and dynamic characteristics of the user. A user profile model is created by acquiring profile properties of individual user using questionnaire and focused more on static user characteristics. Dynamic and temporal characteristics are not incorporated.

Dynamic characteristics learner interest is considered in the following user profile construction: A user profile is created in "music" domain using user's current interests and new interests by analyzing user web logs. User profile is updated with the new interest using a newly introduced concept of ontology based semantic similarity. Interested terms of the learner are extracted by analyzing the web log. Vector Space Model (VSM) used to extract feature from document. A fuzzy clustering method classifies the learners for their interests which recommends using ontology based user profiles to maintain sophisticated representations of personal interest profiles. Each user profile is built from learning objects published by the user himself. Automatically generated fuzzy ontology is used to represent the user profile based on the user's interests and preferences. User profile is built from the learning objects published by the user into a learning object repository. It uses fuzzy ontology to represent user profile into a recommender engine and enhances the user's activities into e-learning environments. An ontology based user profile is constructed using fuzzy clustering technique. The method allows some information to belong to several user profiles simultaneously with different degrees of accuracy. User profile is created by collecting information using meta search in user's blog, personal/organization, web page, and any other sites. WordNet and Lexico-Syntactic pattern for hyponyms were used to extract feature from document. This profile is further improved by applying an ontology matching approach to learn the profile with other similar user.

Learner Interest and Learning style are considered in user profile construction by analyzing the web log. Ontology-based representation using WordNet is used to extract features from documents which solve the semantic inadequacy of VSM model. Fuzzy technique is used to classify the learners for their interests and Felder-Silverman

Learning style model is used to reflect the intrinsic style of the learners.
Fuzzy semantic retrieval is proposed in Electronic Commerce and Traffic Information Service domain using the concept of fuzzy linguistic variable. Query expansion done in SPARQL query language by semantic relations between fuzzy concepts and achieved semantic retrieval of e-commerce and traffic information through fuzzy concepts on the Semantic Web.
The proposed work is to develop an ontology based semantic learner profile which includes both static and dynamic information of the learner such as age, gender, education, interest, learning style etc. The created ontology is then updated automatically to incorporate dynamic characteristics of the learner when new documents are selected by the learner. Finally provide an efficient fuzzy semantic retrieval of information from learner profile by taking advantage of the concept of fuzzy linguistic variable which improves the efficiency of information retrieval and filtering.

SYSTEM MODEL

The proposed approach can provide learner profile according to the learner's individual differences which enhance the process of locating precise learning resources.
The system intervenes at four stages during the process of learner profile construction as shown in Figures 1. First stage is data collection which controls the process of collecting static and dynamic data of the learner. Second stage is learner profile construction which uses ontology to construct learner profile based on the collected information. Third stage is the learner profile updation which updates the learner profile automatically during the adaptation process. Final stage is the fuzzy semantic retrieval which performs retrieval of semantic information from learner profile with the help of fuzzy linguistic variable.

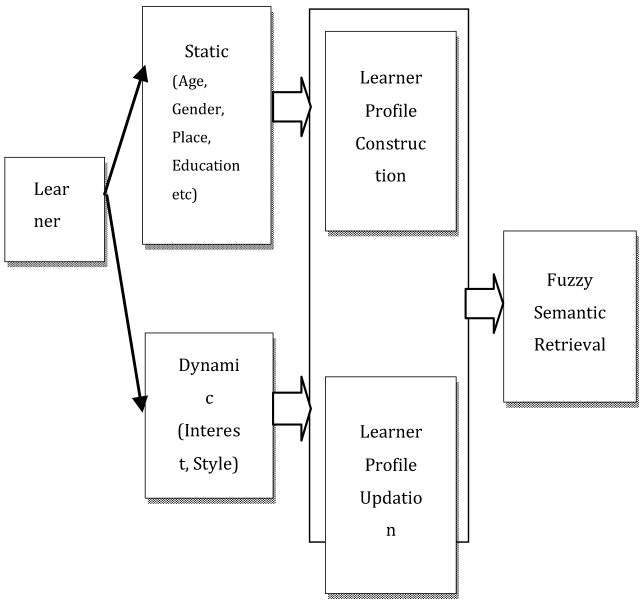


Figure 1: Learner Profile Construction Process

METHODS

Data Collection

There are two types of data about the learner. They are knowledge based i.e., explicit and behavior based i.e., implicit.
Knowledge Based Information: Otherwise called as static. It includes personal Information of learner such as gender, age, place (city, state, and country), education etc. It can be obtained when the learner fill the registration form of the site and this profile is stored in the database. This method is time consuming for users.
Behavior Based Information: Otherwise called as dynamic. It includes information such as learner interest, learning style, learner preferences etc. It can be obtained by analyzing the web pages that the learner visits (i.e., web access patterns) in web server logs. Learner Interest and Learning style are considered in the proposed system as it of particular importance for most learner profiles.
Acquiring Learner Interest: Learner Interest can be obtained from the documents visited by the learner by performing web log analysis. Figures 2 shows the basic steps used for acquiring learner interest. Weblog from learner are first preprocessed as data in its raw form is not suitable for the application of data mining algorithms. Data preprocessing process includes steps like data cleaning, learner identification, session identification, path completion, formatting etc.
Next step is the effective representation of documents selected by the learner. Various methods are used to extract features from the documents. The Vector Space Model (VSM) is adapted to achieve effective representations of documents which extract interested items in the web page. In VSM, each document is identified by n-dimensional feature vector in which each dimension corresponds to a distinct term. The term frequency used to reveal the importance of term within a particular document. Ontology-based representation using Word Net is used to identify Word Net concepts related to document terms. This method improves the performance of traditional VSM model by providing semantics to the terms. WordNet and Lexico-Syntactic pattern for hyponyms were used to extract feature from document.
Domain concept filtering is used to compare extracted concepts with the domain ontology to check the relevant items and the most relevant ones update the learner profile. The items relevance is based on ontology-based semantic similarity where browsed items by a learner on the web are compared to the items from domain ontology and learner profile.

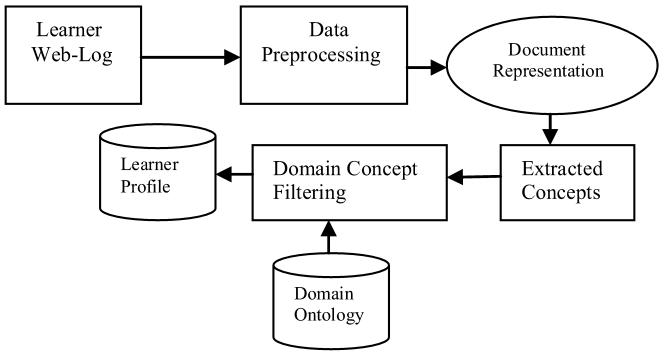


Figure 2: Acquiring Learner Interest

Acquiring Learning Style: Learning style is typically defined as the way the learner prefers to learn. Everyone has his/her own style on learning which can also vary from one situation to another. This learning style can be identified by the learner action on the site. More profound models used for learning style are: Kolb's learning style model and Felder-Silverman learning style model.

The Kolb Learning Style Inventory (LSI) has a forced-choice ranking method to assess students' preferred modes of learning. The students complete twelve sentences about their preferred way of learning. Each sentence has four endings and the individuals are asked to rank the endings according to what best describes how they learn (4 = most like you; 1 = least like you).

Felder-Silverman learning style model defines four dimensions on learning style such as active/reflective, sensing/intuitive, verbal/visual, sequential/global. The analysis of the log files provides a summary of what content items the learner chose to use. The learning styles proposed by Felder-Silverman learning style model are matched to the learner actions as shown in Figures 3:

Parameter	**Value**	**FSLSM Category**
No. of visits/postings in forum/chat	High	Active Verbal
No. of visits and time spent on exercises	High	Active Intuitive
Amount of time dealt with reading material	High	Reflective
Performance on questions regarding theories	High	Intuitive
Performance on questions regarding facts	High	Sensing
Amount of time spent on a Test	High	Sensing
No. of revisions before handing in a test	High	Sensing
No. of performed tests	High	Sensing
No. of visits and time spent on examples	High	Sensing
Amount of time spent on contents with graphics	High	Visual
Performance in questions related to graphics	High	Visual
Performance on questions related to overview of concepts and connections between concepts	High	Global

Figure 3: Relationship between Learner Actions and (FSLSM) category.

Learner Profile Construction

Ontology is used for the learner profile construction. Ontology represents the knowledge in a domain in a structured way. It is a conceptualization of a domain into a human understandable, machine-readable format consisting of entities, attributes, relationships, and axioms. It is used as a standard knowledge representation for the semantic web.

The main steps used in the ontology construction are (Figures 4): Enumerate important concepts and terms which collect terms related to learner, Define concepts, slots and relation of concepts which create preliminary concepts and sub concepts and create relationships between the concept, Implementation which is performed with the help of software and Evaluation which check whether the created ontology is accurate or not.

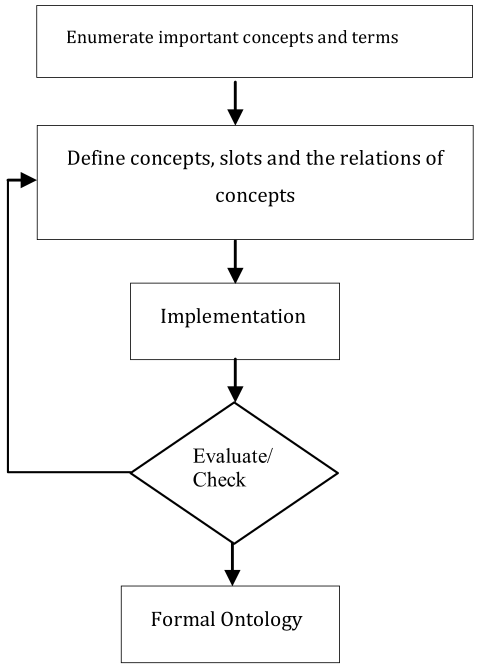


Figure 4: Steps of Ontology Construction

Learner Profile Updation

Learner profile updation allows the inclusion of new concepts into the learner profile when new concepts are selected by learners. Semantic Similarity is the general method used for the learner profile updation. It is used to quantify concept similarities in a given ontology. It compares new concepts with concepts from a learner profile based on the following condition: If the concept does not exist in the learner relevant terms set, then it is incorporated, and its weight value does not change. If the concept already exists, then the concept weight is updated with the new value.

There are multiple ways of calculating similarity of concepts/individuals in an ontology. The most efficient method that matches with the human intuition is based on ontology nodes (classes). In the node-based approach similarity is just a distance between the nodes that are being compared. In the edge-based approach similarity is defined as the minimum number of edges between two concept nodes. The main problem with these approaches is the assumption that links in the ontology is uniform. This can be addressed by a notion of weighted edges. Different methods of assigning weights are introduced such as network density, node depth, type of link and strength of each specific child link. A similarity function approach used to calculate the similarity defines the weighted sum of three different similarities. Ontology-based semantic similarity is used to compare items browsed by a user on the web with the items from a user's profile.

Fuzzy Semantic Information Retrieval

Fuzzy ontology contains fuzzy concepts and fuzzy memberships which allow easy determination of the precise meaning of a word as it relates to a document collection. It can be used in information retrieval to locate precise information, which may be contained in a document content collection. Fuzzy ontology based retrieval system is a system that typically measures the relevance of documents to learner's query based on meaning of dominant words in each document. It determines semantic equivalence between terms in a query and terms in a document by relating the synonyms of query terms with those of document terms.

In the proposed system, fuzzy semantic retrieval is performed with the help of fuzzy linguistic variable. This variable is used for the classification and retrieval of learner profile. It uses three main steps: Define Linguistic Variable, Define Membership Functions, and Define Semantic Relation between Fuzzy Concepts

Define Linguistic Variable: Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. A linguistic variable is generally decomposed into a set of linguistic terms. Example: Age (a) is the linguistic variable. Linguistic terms A(a) = {old, middle-aged, midlife, youth, youngster, adult , …} covers overall values of the age.

Define Membership Functions: A membership function is used to quantify a linguistic term. Different forms of membership functions are triangular, trapezoidal, piecewise linear, Gaussian, or singleton. Membership function can be context dependent and generally chosen arbitrarily according to the user experience. Example: Linguistic terms "youngster" ≤ "midlife" ≤ "old".

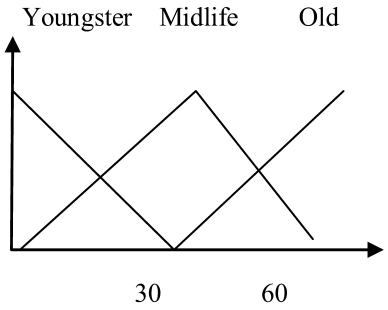


Figure 5: Triangular Membership function

Define Semantic Relation between Fuzzy Concepts: Semantic relation between fuzzy concepts is defined such as equal to (=), less than or equal (≤) and greater than or equal (≥), subset of (⊆) etc. Example: "middle-aged" = "midlife", "old" ⊆ "adult", "middle-aged" ⊆ "adult", "youth" ⊆ "adult".

CONCLUSION

The proposed system is an attempt to implement an ontology based learner profiles that incorporates sophisticated representation of static and dynamic characteristics of a learner which can be utilized for effective information retrieval.

The system will provide personalized learning process to the learner based on their individual characteristic such as age, education, interest, learning style etc. It helps staffs to understand the learning process of learners, and adjust the pedagogical activities, and support the course development. It also supports self directed learning and collaborative learning.

Ontology-based semantic information retrieval is one of the motivations of the Semantic Web. The system proposes an efficient fuzzy semantic retrieval which enhances the performance of tasks such as filtering and information retrieval by using the concept of fuzzy linguistic variable.

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PROJECT PLANNING

A GENE EXPRESSION PROGRAMMING APPROACH FOR OPTIMIZING TECHNICAL RULES IN THE FOREIGN EXCHANGE MARKET

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KEYWORDS
Technical Analysis, Technical Indicators, Evolutionary Algorithm, Gene Expression Programming.

ABSTRACT

Technical analysis is an analysis methodology that deploys past price behavior (and other market data) to guide future trading strategies in financial markets. It involves the use of technical indicators, which are indices formed from combination of current and past price data. Technical indicators are broadly used among traders and financial professionals. Despite their popularity, a number of commonly used technical indicators can be loss-making when applied independently. Technical indicators can be classified into two categories: leading and lagging indicators. While the former performs best within non-trending trading periods, the latter is well-known for its performance during trending trading intervals. In this paper, we propose an evolutionary algorithm: Gene Expression Programming (GEP) as an optimization technique to seek an optimal profit-making combination of both leading and lagging technical indicators. Our aim is to harness the efficiency of both types of technical indicators. Experimental results demonstrate that the optimized set of rules obtained using the GEP trading system can improve the estimation of the market actions.

INTRODUCTION

The foreign exchange market (Forex) is a financial market, where central banks act as intermidiaries between actual traders of currencies [1]. These could be governments, businesses and/or inviduals [2]. Technical analysis is an analysis methodology that deploys past price behavior (and other market data) to guide future trading strategies in financial markets [3]. Theoretically, it postulates that the market's price at a given time reflects all relevant information. Hence, predicting future price can be achieved by considering past price behavior, which in turn follows predictable traces due to traders' repeated patterns of behavior [4]. Methodologically, technical analysis relies on technical indicators: indices formed by combining past and current price data.

Several studies provided direct support for the predictive quality of technical indicators [5]. However, a number of popular technical indicators can be loss-making when applied independently. According to their design, technical indicators are either leading or lagging. Leading indicators are designed precede price movements, which makes them predictive. Lagging indicators follow the price action and are commonly referred to as trend-following indicators. Leading indicators perform best during periods of sideways or non-trending trading ranges, while lagging indicators are considered more valuable during trending periods. Technical traders prefer to use a combination of both leading and lagging technical indicators in order to harness the power of the two types. There is empirical evidence that the automated trading systems that rely on technical indicators have predictive value regarding future movements of Foreign Exchange price, as we will demonstrate in the next section.

In this paper, we propose an evolutionary algorithm, Gene Expression programming (GEP) as an optimization technique to seek an optimal profit-making combination of both leading and lagging technical indicators, in order to harness the power of the two types. In our work we employ the Simple Moving Average (SMA), the Dual Moving Average Crossover (DMAC) as lagging indicators and the Relative Strength Index (RSI) as a leading indicator. We are not concern here in developing trading systems that generate buy/sell signals which may limit the traders choices of trading duration: intraday trading or position trading. The main contribution of this paper is to develop a trend-following system capable of predicting the upcoming market trend direction with a high level of confidence. We believe that, the suggested approach will give the traders the freedom to create their own trading strategy and trading duration. The paper is organized as follows: Section 2 presents the related work. In section 3 we preview the employed technical indicators. Section 4 defines the problem, whereas the following section delineates the proposed solution. Experimental results and Conclusions are represented in sections 6 and 7, respectively.

RELATED WORKS

Genetic Algorithms

Genetic Algorithms (GAs) are stochastic search and optimization methods inspired by biological evolution. First proposed by Holland [6], GAs have been successfully applied to a variety of problems, ranging from. In financial markets, the application of Genetic Algorithm as an optimization technique has experienced significant growth. For example, in [7] a GA has been used as an optimizer of trading strategies on the Foreign Exchange market. The authors proposed a system with a Genetic Algorithm engine

to emulate trader behavior on the Foreign Exchange market and to find the most profitable trading strategy. Recently, there has been works that used genetic algorithms to adjust technical trading rules parameters in background of financial markets [8]. The experimental results based on real time-series data demonstrate that the optimized rule obtained using the GA can increase the profit. Nevertheless, in traditional Genetic Algorithms, genetic structures are represented as character strings of fixed length. This representation is restrictive when the size of the solution cannot be assessed earlier. In [9], a Genetic Programming rather than GA has been used to find technical trading rules for a composite stock index. Genetic programming is an extension of genetic algorithms that allows string length to vary within the solution space [10]. The aim of the proposed algorithm is to find decision rules that divide days into two distinct categories, either "in" the market or "out" of the market. Unlike researches in this area, a Genetic Algorithm system has been proposed to automatically generate trading rules based on technical indexes by calculating the most appropriate trade timing, instead of predicting the trading prices [11]. More recently, Visoiu used gene expression programming to generate buy and sell trading rules are generated using Gene Expression Programmin [12]. The conclusions highlight the positive results obtained in deriving useful trading rules.

Technical Analysis

Technical analysis is the study of historical price movements and/or trading volume to guide trading decisions in financial markets. Technical analysis is based on three basic principles (Murphy, 1986), namely: (i) market action discounts everything, (ii) price move in trends and (iii) history repeats itself.
Technical analysis often involves technical indicators, which are indices formed from combination of current and past price data. We will employ a there types of popular indicators, namely Simple Moving Average, Dual Moving Average Crossover, and Relative Strength Index (RSI).

The Simple Moving Average (SMA)
The simplest of all indicators is the Moving Average (MA) that shows the average value of prices during a defined period of time. For example, if a 10-day average of closing prices is desired, the prices for the last ten days are added up and the total is divided by ten. The term moving is used because only the latest ten days' prices are used in the calculation. Therefore, the body of the data moves forward with each new trading day.

The Dual Moving Average Crossover (DMAC)
The concept of a dual moving average crossover is fairly straightforward. Calculate two moving averages of exchange rates of a currency. One average would be the short term (ST); relative to the other moving average, and the other long term (LT). The technical Approach suggests that when the Short Term Moving Average (STMA) moves above the LTMA, that represents an upward trend signal. (Conversely, when the STMA moves below the LTMA, the Technical Approach indicates a downward trend signal).

The Relative Strenght Index (RSI)
RSI measures the momentum of price movements. It is also plotted on a scale ranging from 0 to 100. Traders tend to look at RSI readings over 70 as an indicator of a market that is overbought or susceptible to a downturn. Readings under 30 characterise a market that is oversold or ready to turn higher. The formula for the RSI is as follows:

$$RSI = 100 - 100/(1+RS)$$

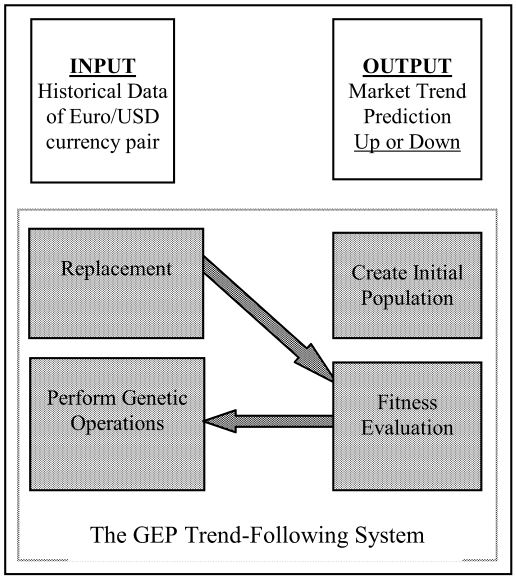
with RS as the ratio of upward averages to downward averages of market closes within periods of *n* days.

The Current Work

Technical indicators are used to interpret Forex market trends and make investment decisions. The main difficulty of its usage lies in the fact that it is extremely hard to reliably construct an instance of any technical indicators with appropriate parameters for a particular series of Forex prices. Also, technical indicators can be classified into two categories: leading indicators and lagging indicators. Leading indicators are designed to lead price movements. Lagging indicators follow the price action and are commonly referred to as trend-following indicators. Leading indicators perform best during periods of sideways or non-trending trading ranges, while lagging indicators are considered more valuable during trending periods. Therefore, in this work we propose an evolutionary algorithm, gene expression programming as an approach for optimizing the combination of both leading indicators and lagging indicators with a variety of time periods (i.e. 5-days moving average, 10-days moving average, RSI of 9-days, RSI of 14-days, etc).

The Proposed GEP Trend-Following System
Gene expression programming (GEP) is employed to find a linear formula of technical indicators to predict the market trend. The generated 'linear formula' consists of both leading and lagging technical indicators. We used two lagging indicators: The Simple Moving Average (SMA) and The Dual Moving Average Crossover (DMAC) and one leading indicator: The Relative Strength Index (RSI). Gene expression programming (GEP) resembles the genetic algorithm in that it goes through the generation of population, fitness calculation, and crossover and mutation stages until convergence is achieved or the maximum allowed number of iterations has reached [13]. The fundamental difference between GEP and the other genetic algorithms is in the translation phase of gene expression where the segments resulted from expression here are of different sizes and shapes, although the genes and the chromosomes were linear of fixed lengths. The proposed GEP Trend-Following System diagram is shown in Fig. 1.
This work is based on the daily data of Euro/USD, through year 2007. Euro/USD is the most commonly traded currency pair in the world.
There are two goals for the proposed system. First, using the technical indicators SMA and DMAC to predict upcoming market trend and evaluate its strength. Second, employing the RSI technical indicator to confirm or reverse the currently prevalent trend.

Our system is designed to keep a trader in the market only when there is a high degree of certainty regarding trend direction. The system generates the signal 'uncertain case' when the price starts to fluctuate in the market, as we will explain in the next section.



Figures 1: The GEP Trend-Following System Diagram

The Representation Step
The size of the gene is equal to variable number of elements. Each gene has two parts, the head, which is the part where the defined operators reside and the tail that is a set of operands. A group of genes represent a chromosome. The descriptions of the operators and the operands used are as follows:

1. SMA(N): an operand type which calculates the moving average of N days. A predictive decision can be made in case of the current price is greater (or less) than the value of SMA(N). In the first case, it is indicative for an upward trend, whereas the second case is indicative for a downward trend. Otherwise, price trend is doomed as uncertain.

2. DMAC: a binary operator that predicts an upward trend if the simple moving average of a short-term period, i.e., SMA(N_ST) has a higher value than that of a simple moving average of a long-term period (SMA(N_LT)). The opposite relation yields a prediction of a downward trend. Are both values equal, the operator implies an uncertain decision.

3. RSI: an unary operator that determines whether to hold on direction of predictions or reverse it according according to the following algorithm:

if ((RSI < 30 or RSI >70) and (SMA(N) ≠ current market price))
    reverse the direction of trend predicted by SMA(N)
elseif ((30 ≤ RSI ≤ 70) and (SMA(N) ≠ current market price))
    confirm the direction of ternd predicted by SMA(N)
else
    return 'uncertain case'.

Design of the GEP Algorithm

Population
The individuals of the population or the chromosomes are generated randomly. Each element in the gene is generated randomly such that the chromosome structure remains intact.

Evaluation
The individuals or the chromosome of the population are evaluated according to the fitness function:

$$F = max\ (P)$$

where

$$P = \beta\ \alpha_{eff} + (1 - \beta)\ \alpha_{ta}$$

with

$$\alpha_{ta} = (\sum P_i / N_{tot})\ \%$$

and $i = 1,2,3 \ldots N_{tot}$

Here, the parameters have the following meaning:

P: Prediction of market action in %.
α_{ta} : Prediction made by the technical indicators during the evaluation period in %.
α_{eff} : The effect of fundamental factors during the evaluation period in %.
P_i : Prediction in day i made by the GEP system
(P_i = 1 correct prediction, P_i = 0 wrong prediction)
N_{tot} : the total number of days in the evolution period.
β and $(1 - \beta)$: The weight given to α_{eff} and α_{ta}

Selection
We used the roulette selection, to ensure that fitter individuals have more chances to be selected than less individuals with less fitness values.

Translation
The translation phase is the process where coded information of each gene (genotype) is transformed to give characteristics encoded by that gene (phenotype). Here, the genotype which is just a set of numbers representing the operators and operands will be translated to expression trees and then to formulas.

Modification
The modification on individuals in GEP occurs according to two types of operators, recombination and mutation.

Recombination
In the proposed system GEP there are three types of recombination. The first one called one point recombination and occurs when the chromosomes of two individual cross over at a randomly chosen point to form off springs. The second occur when the chromosomes are crossover two randomly chosen points, and the third occur when the crossover points were at any gene end points.

Mutation

The Mutation operator is used to introduce new non-inherited features into chromosomes. The mutation can occur in the head part of the gene only, so that the structure of the chromosome remains intact.

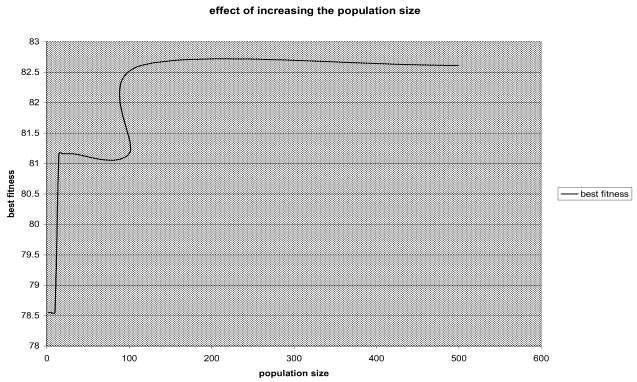
SIMULATION RESULTS

In case of applying the moving average alone, the resulted fitness's is lower than the fitness's obtained after applying the GEP (Tab. 1).

Table 1: Fitness Values for Various Moving Averages

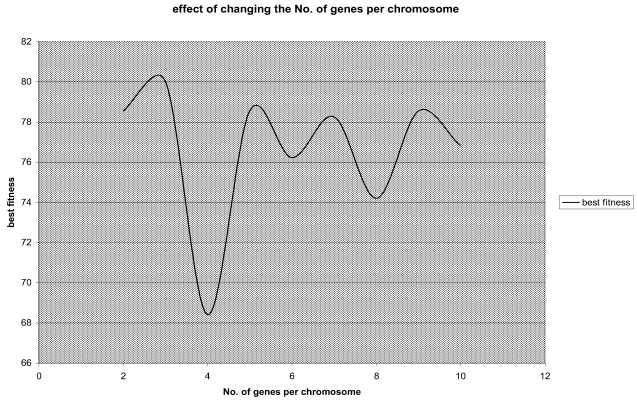
Moving Average Period	Fitness (%)
5	75.072464
10	76.521736
15	77.391304
16	78.260872
20	77.68116

Increasing the population size increases the corresponding value of the best fitness obtained. Average results of ten runs are shown in Fig. 2.



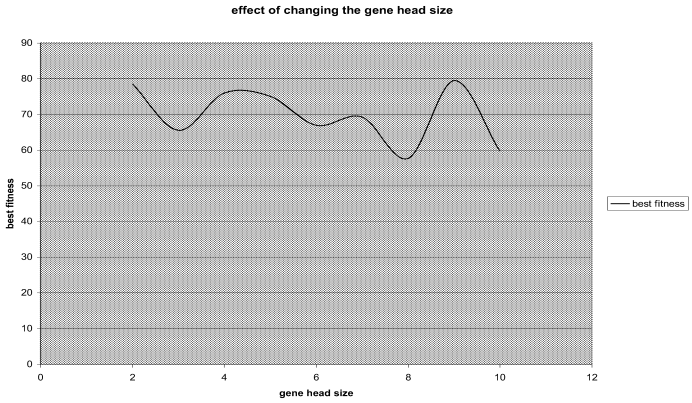
Figures 2: The Effect of Increasing the Population Size

If we increase the number of genes per chromosome, the best fitness value will fluctuate between 80 and 68.4 (the effect is not clear). The results of ten runs are shown in Fig. 3.



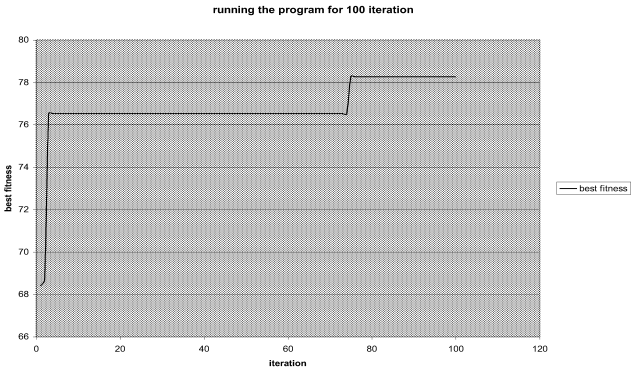
Figures 3: The Effect of Increasing number of Genes per Chromosome

If we increase the gene head size, the best fitness value will fluctuate between 79.42 and 57.68 (the effect is not clear), the results of ten runs are shown in Fig. 4.



Figures 4: The Effect of Increasing the Gene Head Size

Running the program for 100 generations, the best fitness value increases as the number of generations increases. Corresponding results are shown in Fig. 5.



Figures 5: Fitness Values for 100 Generations

CONCLUSION AND FUTURE WORK

In this paper, we deployed gene expression programming (GEP) as an optimization technique to find an optimal combination of both leading and lagging technical indicators. Our experimental results show that the optimized set of indicators obtained using the GEP trend-following system outperform the SMA indicator; applied with different time frames, in predicting the market action. Also, the best fitness value increases when we increase the population size. Possible improvements include the use of more indicators, and development of more sophisticated fitness function.

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A REFERENCE MODEL TO SUPPORT PUBLIC PROCUREMENT PROJECT PLANNING

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KEYWORDS
Public Procurement, Public Tender, Project Management, Risk Management, Bullwhip Effect, Supply Chain Management.

ABSTRACT

In this paper a reference model to support the fast development of accurate project plans for public procurement is proposed, aiming to support the standardization of the procurement project leading to shorter award lead times and overall supply chain cost reduction.
The development of a project plan for projects of public interest is considered as a difficult and time-consuming task. Important constraints are the legal frame and the procurements' completion time. On the other hand failing to plan, organize and implement a systematic process of call for tenders, bidding evaluation and awarding the procurement order can lead to substantial time delays, prolonged and unjustified resource commitment, planning failures and managerial discomfort for both buying and selling organizations.
The proposed reference model is compatible with the Greek Organization for Standardization standard ELOT 1429:2008 "Managerial capability of organizations implementing projects of public interest – requirements" which is used by the Greek State as a managerial maturity model for organizations involved in the implementation of projects funded by the European Community Support Framework.
The model addresses four out of the ten subject groups included in the ISO21500:2012 "Guidance on project management" standard namely:
Scope, by including a reference work breakdown structure for procurement through public tenders.
Resources, with a reference set of necessary resources (resource sheet).
Time, including a reference project schedule with estimated durations for each activity.
Risk, including a reference risk breakdown structure and assessment of the identified risks.
A case study is also presented. It concerns a project included in a program (set of projects) aimed at completing the National Cadastre for the whole country by 2020. This particular project, a public tender, was chosen because its successful completion is critical for the early start of the contract's implementation. Due to the long delays in awarding contracts of the previous tenders for cadastral projects, and given the importance of this specific tender, it is crucial to develop an accurate project plan, identify the related risks and come out with a realistic estimation about the project's duration.

LITERATURE REVIEW

Procurement is an important subject group within a project and comprises the processes of planning the procurements, selecting the suppliers and administering the procurements (ISO 2012). Procurement is often organized as a separate project as is always the case for procurements through public tenders.
Accurate procurement project planning is the equivalent of production planning on the upstream/buy side of an organization's supply chain, a process of great significance and complexity (Ponis et al., 2007). In addition to the eventuality of inadequate procurement project planning, the absence of a standard way of communicating project information creates an information distortion further adding to the amplification of demand fluctuations, especially for supplying/bidding organizations, a phenomenon also found in literature under the term, 'Bullwhip Effect' (Lee et al., 1997, Ponis and Koronis, 2012).
Procurement through public tenders is a critical stage for the successful implementation of important programs and projects of the public sector. Even though the knowledge and skills of personnel involved are important for the successful delivery of projects, they are not sufficient by themselves. Especially, in cases of programs, where a strategic vision has to be implemented and the level of uncertainty is quite high, what is required, as well, is the managerial capability of the organizations.
The need to improve the managerial capability of organizations both in the public and private sector has been widely recognized. This is demonstrated with the development of a number of maturity models (Andersen and Jessen 2003; Kerzner 2001; McCauley 1993; Paulk et al. 1999; PMI 2003; Shrum and Phillips 2004).
The Greek State uses the ELOT 1429:2008 standard issued by the Greek Organization for Standardization (ELOT 2008),

as a managerial maturity model for organizations involved in the implementation of European Community Support Framework. The standard sets requirements for the managerial capability of organizations implementing projects of public interest. Aim of the standard is to enhance the probability of a project's success (Fitsilis et al. 2011).

Project management success is the appreciation of the project management results by the relevant interested parties (Caupin et al., 2006). Although successful implementation of projects is a vital issue for project-based enterprises, managers usually confuse the success of a project with the project management success. These two instances of success despite being highly related, are not the same as project success is related to program objectives that might change from external factors, while project management success is closely related to the objectives assigned to the project manager and have to be met.

Project management success is usually measured against the four project objectives namely cost, time, scope and quality (Kerzner, 2013). However, the risk factor is the one which mostly determines the success or failure of a project (Johnson, 2006). Project risk has been defined as *an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality. A risk may have one or more causes and, if it occurs, one or more impacts* (PMI, 2013). The main objective of project risk management is to "increase the probability and impact of positive events, and decrease the probability and impact of negative events in the project" (PMI, 2013).

Project risk management consists of four basic phases, which are risk identification, risk assessment, risk treatment (mitigation) and risk control (follow up) (Leopoulos and Kirytopoulos, 2002; 2004). The proposed reference model focuses on evaluating project risk management with respect to time management as the procurements' completion time is a critical index for the project's success.

Project time management includes the processes required to accomplish timely completion of the project (PMI, 2013). The core processes of project time management include activity definition, activity sequencing, activity resource estimating, activity duration estimating, schedule development and schedule control. The outcome of project time management is a project schedule that includes start and finish dates of each activity. Even if no risks appear, the project is unlikely to finish on schedule if either the duration of activities or the definition of dependencies is not realistic (Kirytopoulos et al., 2007).

The rest of the paper is organized as follows: in section 2 the reference model for developing a project plan for procurement through a public tender according to the Greek legislation and practice is presented and in section 3 a case study is used to showcase the reference model's implementation. Finally, section 4 presents conclusions and directions for future research.

THE REFERENCE MODEL

The model of the project addresses four out of the ten subject groups included in the ISO21500:2012 standard.

1. Scope 4.3.11 Define scope, 4.3.12 Create work breakdown structure 4.3.13 Define activities 4.3.14 Control scope
2. Resource 4.3.15 Establish project team 4.3.16 Estimate resources 4.3.17 Define project organization 4.3.18 Develop project team 4.3.19 Control resources 4.3.20 Manage project team
3. Time 4.3.21 Sequence activities 4.3.22 Estimate activity durations 4.3.23 Develop Schedule
4. Risk 4.3.28 Identify risks 4.3.29 Assess risks 4.3.30 Treat risks 4.3.31 Control risks

In order to collect the necessary information both top down and bottom up approaches have been applied.

Work breakdown structure

First the steps included in the relevant legislation, mainly law 3316/2005, have been transformed in work elements and included in a work breakdown structure (top down approach). Second a series of interviews has been conducted with important stakeholders of the tender under consideration (see the case study below) but also experts in conducting public tenders. The latter are employees with wide experience of participation as chairmen or members of committees which supervised previous tenders. The steps suggested by the experts have been transformed in work elements and included also in the model work breakdown structure.

Third, files from projects already implemented have been consulted. The data have been treated accordingly in order to define generic work elements (see **Fig. 1**) repeated in the various tenders (bottom up approach).

The lower level of the WBS was then used in order to define the activities of the project. The reference model comprises 130 activities necessary for the completion of the tender (see **Table 1**).

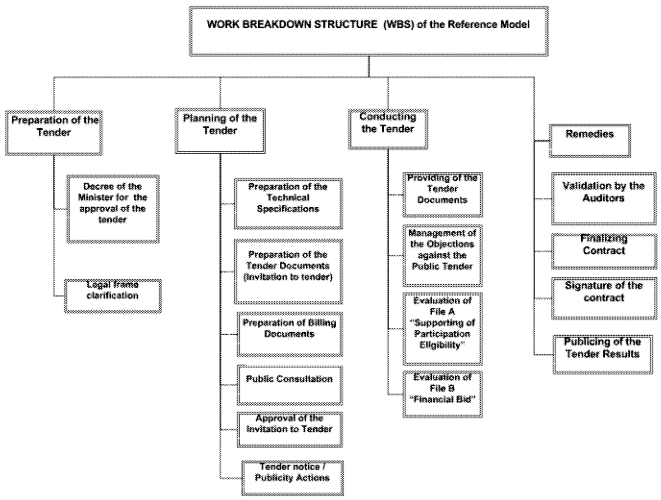


Figure 1. Work Breakdown Structure

Resource estimation

Similarly the resources compulsory to carry out the tender as described in the legislation have been attached to the relevant activities.

Further, the experts estimated the additional resources necessary for the activities' implementation. The reference model comprises 35 different generic resources of work type necessary for the public tender.

3	**Planning of the Tender**
3.1	Preparation of the Technical Specifications
3.1.1	Preparation of the Technical Specifications (draft)
3.1.2	Review of the Technical Specifications
3.1.3	Modification of the Technical Specifications according to the comments on the Public Consultation and the legislation.
3.1.4	Completion of the modification of the Technical Specifications - submission for approval in the BoD
3.1.5	Submission of the final version of the Technical Specifications in the Minister
3.1.6	Completion of the review of the Technical Specifications (milestone)
3.2	Preparing of the Tender Documents by the Project Division / approval by the BoD
3.2.1	Appointing the persons responsible for the preparation of the tender documents
3.2.2	Preparation of Project Folder
3.2.3	Definition of the number of contracts
3.2.4	Preparation of the contract document regarding the obligations of the contractors
3.2.5	Preparation of the draft documents of the tender
3.2.6	Modification of the Tender Documents according to the comments on the Public Consultation
3.2.7	Submission of the Tender Documents for approval in the BoD
3.2.8	Update of the Project 's Folder
3.2.9	Submission of the final version of the Tender's Documents in the Minister
3.2.10	Completion of the preparation of the Tender Documents

Table 1. Activity list

Time

The sequence of the activities was first based on the requirements of the legislation and was accordingly included in the model. The experts determined the sequencing of the rest of the activities. All these activities are constraints finish to start.

For the activities of the project for which specific deadlines are provided by the existing legal frame, the estimation of duration is deterministic (e.g., the duration for issuing the evaluation of the supporting documents is set at 75 days).

The model project schedule was then developed.

Risk

Identification of Risks

To identify the risks, threats or opportunities, a risk breakdown structure (RBS) was developed.

First, uncertain events foreseen in the relevant legislation (e.g. eventual appeals against the technical specifications of the tender), have been transformed in risk terminology and included in the risk breakdown structure.

The appearance of such a risk modifies radically the project's duration so these risks were treated as different scenarios of the project's implementation.

Second, risks suggested by the experts have been included in the model risk breakdown structure. These risks have been assessed using a qualitative scale.

No of Risk	WBS Code	Description of Activity	Desciption of Risk
2	4.1.8	Appointment of the members of the Tender Committee by the BoD.	It is possible that the qualified employees are not willing to participate as Chairmen or members of the Tender Committee
3	4.4.12 (CPM)	Decision of the BoD on appeals against the result of the evaluation of the supporting documents	There may be a delay of the BoD in making a decision on appeals against the decision of approval / non-approval of the evaluation of the supporting documents, due to the large number of appeals received.
	4.5.13 (CPM)	Deadline for submit appeal against the result of the tender	
	4.5.14 (CPM)	Decision of BoD on appeals against the result of the tender	

Table 2. Risk register

The identified risks were, when possible, attached to project's activities.

Based on the above, a risk register has been developed comprising 40 threats and one opportunity (see **Table 2**).

Risk Assessment

Risks identified by the experts have been assessed using qualitative analysis. For each risk a probability and an impact has been estimated leading to the estimation of the risk exposure.

The following scale of probability was used: very low (< 10%), low (10% -30 %) , moderate (30% -50 %), high (50 % -70 %) and very high (> 70%).

The following scale of the impact was used: very low (<5 %), of the activities duration, low (5% -10 %), moderate (10% - 20 % , high (20 % -40 %) and very high (> 40%).

Based on the product of the probability by the impact the risk exposure has been characterized as low, medium or high.

The 40 identified risks have been classified based on risk exposure as: 11 high risk, 22 medium risk, 7 low risk. One opportunity has also been identified.

THE CASE STUDY

The project under consideration is a public tender aiming to implement cadastral studies and includes 28 contracts with a

total budget of € 572 million. The number of the properties to register is estimated about 16.000.000 and amounts to 40% of all proprietary rights in the country. The implementation is divided into 57 regions. The budget for the contracts is estimated between € 10 and € 30 million per contract.

Creation of the Work Breakdown Structure

The tender will be conducted in accordance with the law 3316/2005 along with presidential and ministerial decrees issued in execution of the above mentioned law. For the project under consideration i.e. award of the contracts of the cadastral studies, a special legal frame (law 4164/2013) provides certain exemptions from the general legislation. Due to these exemptions, applicable in the current tender, the activities included in the reference model have to be adapted.

For the adaptation of the phases and the activities of the reference model to the current project, the procurement's documents were used. In addition, interviews with the persons responsible for the tender were conducted namely the manager of the project division, the lawyer from the legal division, the head of the procurement and standards section and a member of the scientific council all with broad experience of participation as members and chairmen of committees in previous tenders.

Project Schedule

The special legal frame exempts the evaluation of the technical offer and decrees as the only award criterion the lowest offer's price. This exemption, applied to the reference model, is expected to shorten the total time of the tender and reduce the time required to complete the whole project of cadastral studies.

Examination of the relevant activities in the reference model, showed that considering the technical offers leads to significant delays in the completion of tendering process. The duration of the activities for the evaluation of the technical offers is important, particularly when there are several bidders per contract.

The project schedule includes 10 phases, 38 summary activities and 85 activities.

Risk Treatment

The exemption of the evaluation of the technical offer eliminates the risks associated with objections, appeals and other remedies exerted by contestants against the evaluation results.

In order to treat the risks associated with appeals against decisions approving the evaluation of the supporting documents two scenarios have been proposed: an optimistic and a pessimistic.

a) in the optimistic scenario was considered that none of these uncertain events will actually happen e.g. submission of objections to the notices, appeals against the decree on approval of the Evaluation Records of File A, or award decisions of the BoD of the company injunctions against decisions on appeals, complaints against acts of Auditors etc. eliminating the durations of the specific activities of the reference model.

b) according to the pessimistic scenario all the activities included in the reference model will have to be executed (e.g. appeals against decisions of the superior authority and applications for interim relief and other remedies).

The estimated duration of the procurement will thus vary by contract. For contracts of cadastral studies concerning areas located a short distance from Athens, a greater number of offers is expected, increasing the chance to apply the pessimistic scenario. In contrast with contracts related to studies for remote mainland areas or islands, where small number of offers or even a single offer per contract will possibly be submitted, the optimistic scenario is expected to apply.

The schedule of project phases, activities and actions of the project, for the optimistic and the pessimistic scenario, is presented in the form of a Gantt Chart (see **Fig. 2**).

In the optimistic scenario, the project will last approximately 22.5 months and it is estimated to be completed around January 2015. According to the pessimistic scenario, the project will last 40 months and is expected to be completed around June 2016. As start date of the project has been taken the date of beginning of the planning of the tender on 04.03.2013.

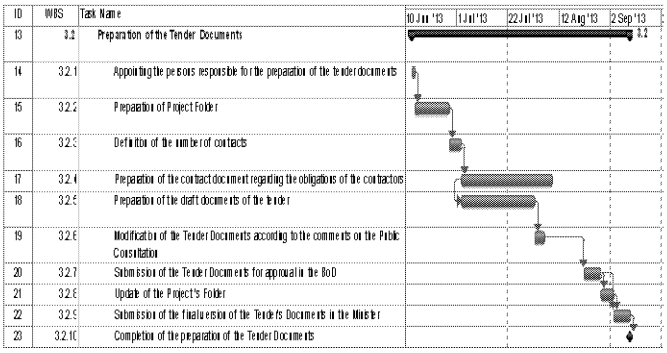


Figure 2. Gantt Chart

CONCLUSIONS AND FURTHER RESEARCH

Procurement through public tenders is a critical stage for the successful implementation of important programs and projects of the public sector.

Procurement through a public tender is organized as a project, where both *project success*, related to an accurate and timely procurement and *project management success* related to the efficient and effective use of public resources are equally important.

The proposed reference model supports the responsible authorities to develop very quickly an accurate project plan for the procurement through public tender. The proposed model incorporates the legal frame and the experience of several experts involved in similar tenders.

In addition, the proposed reference model is compatible with the Greek Standardization Organization ELOT 1429:2008 standard, which is used by the Greek State as a managerial maturity model for organizations involved in the implementation of European Community Support Framework and addresses four out of the ten subject groups included in the ISO21500:2012 standard.

The presented case study, a project included in a program (set of projects) aimed at completing the National Cadastre for the whole country by 2020, highlighted the possibility of the model to be used as a basis in order to develop a project plan quickly and accurately. A realistic estimation of the project's duration is valuable information for the managers of the entire program.

As further research the reference model should address the six other subject groups included in the ISO21500:2012 standard namely: Integration, Stakeholder, Cost, Quality, Procurement and Communication.

A second direction is the quantitative risks assessment combining the expert judgment, statistical data, and other

sources of data, to calculate the probability of occurrence as a distribution function and estimate an amount for each impact. Finally, the PERT method has to be applied. The experts should be able to estimate the optimistic, the most likely and the pessimistic duration for each activity. In that case different scenarios regarding the project duration can be examined with a probability of success for each scenario.

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A SMART PLATFORM FOR DYNAMIC ENTERPRISES COLLABORATION

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KEYWORDS
Distributed Systems, Collaboration, Access Control, Interoperability, Scalability.

ABSTRACT

Current economical and industrial worldwide context asks for an agile and efficient development of collaborating networked enterprises. More and more future manufacturing organizations and networks will be virtual ecosystems in which a large number of Small and Medium Enterprises SMEs are involved in order to create new businesses. In this context, a platform that allows creating flexible and agile communication and collaboration is required. Several research works and projects, as the IMAGINE european project, propose new approaches, methodologies and technical solutions to build this kind of new generation platforms for collaborative and dynamic networked enterprises. The main goal of this paper is to show how we can enhance Dynamic Manufacturing Networks platforms such as the IMAGINE platform in order to make it smart and autonomic by adding mechanisms to allow not only a semantic reconciliation between partners that share heterogeneous services, but also to make the platform more secure and scalable.

INTRODUCTION

Current economical and industrial worldwide context requires an agile and efficient development of collaborating enterprises based on the dynamic interconnection of heterogeneous IT infrastructures. More and more future manufacturing organizations will be virtual ecosystems in which a large number of Small and Medium Enterprises SMEs are involved in order to create new businesses. For that, enterprises have to expose business functionalities as 'services' available through the network, that can be discovered, invoked and exploited by different partners. Inter-enterprise collaborations involve highly distributed and pervasive systems that are more and more designed following a Service-Oriented Architecture (SOA) approach. In such context, the Enterprise Service Bus (ESB) represents an important building block within a service oriented platform. ESBs implement standard-based and distributed integration and mediation strategies allowing various collaborating enterprises to share services and resources.

Several platforms have been proposed to support manufacturing networks. Our work in the IMAGINE project (IMAGINE 2011) is to provide a new generation platform able to satisfy the requirements of dynamic manufacturing networks creation and management. In this paper, we propose additional functionalities to be added to the IMAGINE platform in order to meet additional needs, in particular:

- Secure access to resources according to a set of roles. Managing authorizations is a crucial issue in collaborative manufacturing networks, especially when roles, partners and tasks change dynamically during the production process. Likewise, members may have different roles during the collaboration, such as a coordinator in a project and a provider in another one, while also being the project leader of his organization. This number of roles gives these members different access rights to different resources.
- High performance. Inter-enterprise collaborations may result on a high volume of communications and make complex the management of a large number of heterogeneous and dynamic distributed resources and services. The infrastucture and platform satisfying these needs are going to support a high number of users to access the different services provided by the involved enterprises. In this context, the scalability becomes an important issue.
- Semantic interoperability and reconciliation. With the development of ICT, network enterprises' information systems evolve rapidly. Each enterprise follows their own laws in organizing their business process and services. Data representation and formalization is the main challenge to integrate the different enterprise information systems. The diversity of enterprise information systems and data models creates a high requirement for integrated methods to allow collaboration among the enterprises.

Our work tackles these three main problems by offering new mechanisms for smart management of non functional requirements related to the communication performance, the heterogeneous data integration and the access control to multi-organization resources. In this paper, we propose a semantic-based smart mediator that aims at facilitating enterprises collaborations, relying on decentralized control and self-configuration capabilities. The complexity of the authorizations administration is tackled by following the Role-Based Access Control (RBAC) model, which is a predominant model for access control. The paradigm of autonomic computing and a cloud-based environment are used to deal with the scalability and the efficiency of the smart mediator. Likewise, the data heterogeneity is handled by implementing advanced semantic techniques. An unified layer to describe and formalize data, according to the application context, is also provided.

The paper is organized as follows. Next section introduces a case study based on the collaborative aircraft design in the context of the IMAGINE project. A related works section presents proposals related to access control, scalability, performance and data heterogeneity management. It will follow sections that detail our approach and give validation results. Finally, conclusions and perspectives of this research work will be presented.

USE CASE

IMAGINE research project is an European project that targets the development and delivery of a novel comprehensive methodology and a platform for effective end-to-end management of dynamic manufacturing networks (DMN). It is aimed at supporting the emergence of a powerful and new production model, based on community, collaboration, self-organization and openness (IMAGINE 2011). This will allow boosting the productivity and competitiveness of OEMs and SMEs, which will become more responsive and agile in designing and producing new generation Future-Internet manufacturing applications and systems.

The project's contributions are the IMAGINE DMN lifecycle management methodology and the DMN ICT Platform that supports the proposed methodology (Figure 1).

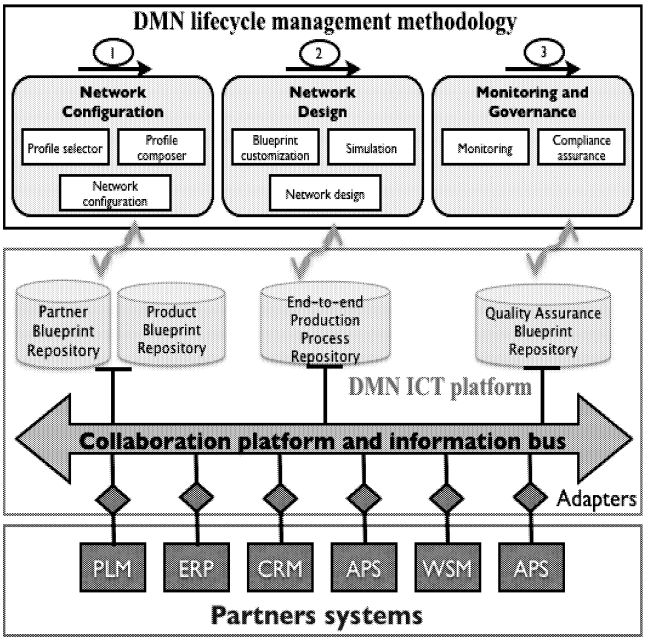


Figure 1: IMAGINE Methodology and Platform

The methodology allows efficiently managing a networked supply chain in three phases: Network Configuration, Network Design, Monitoring and Governance. The Network Configuration phase aims at identifying and selecting partners for a collaboration. During Network Design phase, the production systems of selected partners are interconnected and the end-to-end supply chains processes put in place. The Monitoring and Governance phase aims at managing and controlling at runtime the operations of the network.

The ICT platform gives the technical solutions that effectively enable and support concretly the management of networked manufacturing supply chains. It is based on a set of blueprint repositories that introduce the followed data format model to describe the wanted final product, the partners capacity, the end-to-end process and the needed quality. An Enterprise Service Bus integrates the systems of collaborating partners and allows the access to the blueprint.

It is planned to demonstrate the proposed IMAGINE approach using five living labs (LL), each one with a specific market and business context (Figure 2):

- Aerospace and Defense domain (EADS LL)
- Multi-site single factory domain (IPA LL)
- Furniture Manufacturing domain (AIDIMA LL)
- Car Manufacturing domain (FIAT LL)
- Engineering domain (UoW/WMCCM LL)

For that, the IMAGINE ICT Platform has to be able to support the five living labs. Our work targets satisfiying non-functional requirements of the five LLs, and in particular at two level/goals: first intra LL and after at the generic platform level that needs to support the multitenancy.

- Inside a living lab representing a set of inter-domain collaborations, enterprises have to expose internal processes, tools, services and data integrated through IMAGINE platform. In this context, we can have several issues to cover related to access control, semantic and performance.

For instance within the Aerospace and Defense living lab, the AIRCELLE company will publish information about the nacelles production and the IMAGINE platform has to ensure that this confidential information will not be accessed by AIRCELLE competitors, which don't have the rights.

AIRBUS, Engine Alliance, AIRCELLE, SNECMA, Rolls Royce are part of involved partners in the process of the aircraft production. They publish and share heterogeneous data with a diversity of representation and format. And because they are in different fields, they can have a different perception and understanding of the exchanged data.

The integration part of the IMAGINE ICT platform is based on ESB technologies used as the connectivity layer between all the systems involved in the processes. So, the ESB integrates a large number of systems. And because the design of aircrafts implies an important number of transactions and messages at the IT level within the bus, overload situations for the internal components of the ESB can appear. This can lead to performance degradation.

- Also, the platform is supposed to support in concurrence the five living labs based on the multitenancy concept. Isolation and elasticity paradigms need to be applied to ensure a global quality of service in terms of scalability and confidentiality.

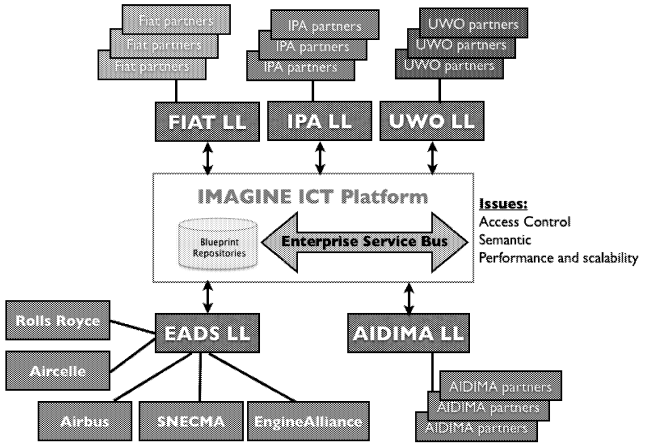


Figure 2: IMAGINE LL Support

New mechanisms for smart management of non functional aspects related to the communication performance, the heterogeneous data integration and the access control to multi-organization resources are offered to tackle these problems.
The next section gives some related works that deal with the same issues.

RELATED WORKS

Several access control models have been studied in (Tolone et al. 2005). Several works use semantic techniques in order to implement Role Based Access Control (RBAC) in collaborative environments. In (Di et al. 2005), an ontology-based approach that implements RBAC constraints is proposed. However, the authors do not provide a complete method to implement all the RBAC features. In (Toninelli et al. 2006), a context-aware access control approach that manages permissions based on users' roles/characteristics and on other contextual information is proposed. Ontology-based methods that support reasoning have been used to define the access control policies. The proposed work does not discuss the inconsistency problem that may arise in this environment since several contextual information are considered. Some work use ontology-based techniques in order to extend the role based access control approach with contextual attributes. For instance, the RBAC approach is extended in (Heilili et al. 2006), with negative authorization and describe how to detect inconsistencies. These two works use ontologies and they do not use reasoning capabilities in order to define access control policies. The authors in (Mohammad et al. 2006), present RBAC mechanisms using ontologies and they exploit semantic rules for reasoning. The proposed solution does not support RBAC constraints. In addition, the proposed model is domain specific and cannot be applied for different organizational structures. The approaches that have extended the RBAC model do not deal with detecting inconsistencies. In our approach, we use ontologies to implement the RBAC model and represent semantic relations between permissions in order avoid inconsistencies when assigning access rights.
The Enterprise Service Bus (Chappel 2004) is the standard based infrastructure allowing an end-to-end Service Oriented Architecture. In fact, distributed services can be composed in order to provide more sophisticated features and functionalities. And the ESB is the middleware able to integrate homogeneous or heterogeneous services. To cope with the limitations of performance due to potential messages losses that can happen when a service or a bus component is overloaded, it is suggested in (Shi 2009) to follow the logic of reliable transport protocols such as TCP (Transmission Control Protocol) in the internet (TCP 1978), by retransmitting requests until the reception of a delivery confirmation or an acknowledgment. Because enterprises have critical applications, (Panahi et al. 2009) proposes runtime service bus to support distributed real-time control systems. In this paper, authors propose a middleware with a service reservation mechanism to ensure end-to-end deadline. To avoid a higher response time, (Liu et al. 2008) proposes an overload control that monitors the flow rate and reduces the number of requests at a specific threshold. (Wu et al. 2009) defines a redundant routing model that tolerates unavailability or failure of the bus component responsible of the routing process. In addition of presented works, we propose to manage dynamically not only the ESB itself but also the IT environment that supports the bus infrastructure. Our approach is based on the elastic dyanimic provisioning of additional resources or instances of the ESB within well adapted topologies (e.g. clusters) in order to respond to scalability requirements.
Wiederhold (Wiederhold 1992) defines the mediator as “a software module that exploits encoded knowledge about some sets or subsets of data to create information for a higher layer of applications”. The mediators are facilities that support an integrated view over multiple information sources in order to provide accessible information according to requirements. The mediator architecture was a potential solution which solves heterogeneity issues well-adapted for heteregeneous domains (Leclercq et al. 1999), (Romanello et al. 2005). Various techniques and tools were proposed to define the mediator architecture. Leclercq *et al.* (Leclercq et al. 1999) were interested in the information interoperability in order to provide the cooperation among geographical spatial information systems. Their work mainly relies on semantic description of context information captured from various spatial systems. They defined two levels in their architecture: the wrapper level to access heterogeneous data and the cooperation level that provide services for facilitating semantic resolution and query processing. Their semantic mediator is based on ontology to describe the cooperative schema. In contrast to our semantic mediator, this work does not tackle the collaboration between the shared data. It provides the integration between the cooperative schemas that have local access to their wrapped data. Another interesting work in the domain of business to business (B2B) is the work of Vujasinovic et al. (Marko et al. 2010). Their work provides a semantic mediation to provide interoperability among heterogeneous enterprises by annotating the exchanged messages. Similar to Vujasinovic et al, our work enriches data with semantics. However, our work is wider because it includes the semantic description of the IT infrastructure in order to provide a detailed view to the ESB which the responsible of ensuring the QoS.

PROPOSED ARCHITECTURE

Overview of the Smart Mediator

The Smart Mediator is composed by a set of components that run on SOA oriented execution platforms. These components can be dynamically configured and aggregated to give a federated and clustered IT infrastructure well suited to provide the required elasticity and multitenancy needs. The next figure 3 presents the Smart Mediator architecture. The main components, including the access control component, the enterprise service bus and the semantic layer, are presented hereafter.

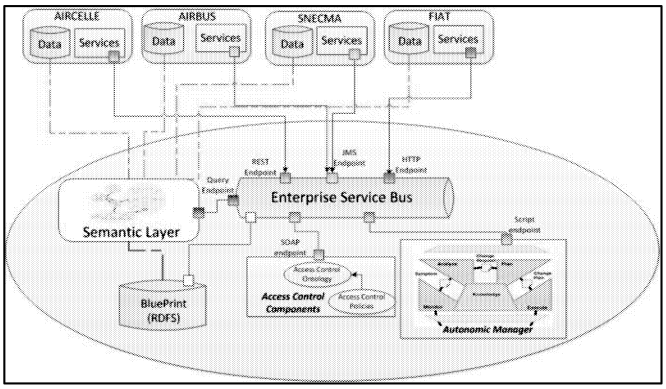


Figure 3: The Smart Mediator for Collaborative Enterprise Network

RBAC based model for Access Control Management

Our solution aims at reducing the complexity of the authorizations administration in large network enterprises. In RBAC, access to resources is based on the roles that the users have in the collaboration process; and permissions are assigned to roles rather than to users. RBAC allows the authorizations administrators to define constraints in order to limit the access rights that are available for users. Despite all benefits of RBAC, some identified weaknesses have to be addressed. Indeed, checking the consistency of the permissions is not possible through the RBAC model. For example, if a user u1 is assigned a permission p1 (read the file F1), and the user has not the permission p2 (access the directory that contains the file F1), then an inconsistency arises. To overcome this problem, a clear semantic description of the permissions is needed. In our work we propose a semantic model based on ontologies in order to enable checking consistencies in the RBAC model.

Figure 4 represents the main part of the access control ontology which has to be specialized to represent each specific domain. The authorizations administrator defines the access control policies based on the elements contained in the ontology such as roles and resources. This ontology consists of the following elements:

- Resource: This concept represents the resources shared between collaborating members. It is the parent class of all resources, which will be represented in the domain-specific ontology. This class can have additional attributes describing the resource depending on the domain.
- Action: This class represents the action that can be performed by a user on a resource. Actions may be read, write, remove, execute, etc. A set of possible actions for each resource has to be defined in the domain ontology. This is possible through the nonfunctional property hasPossibleActions.
- Permission: This concept represents the access right that is assigned to a given role. Two object properties have to be defined for each permission: (1) the hasResource relation relates the permission to a resource, and (2) the hasAction relation relates the permission to one or more actions. Therefore we ensure that each permission is associated with a set of actions and a resource. In order to resolve inconsistencies that may arise when a given permission requires another permission to be performed, we define the requires relation which links two permissions.
- Role: This concept represents the roles that are assigned to users. The permissions are assigned to roles through the nonfunctional property assignedToRole. This relation allows a many-to-many mapping between roles and permissions.
- User: This concept represents users who collaborate using the platform. Roles are assigned to actors through the nonfunctional relation hasRole allowing a many-to-many user-role assignment.

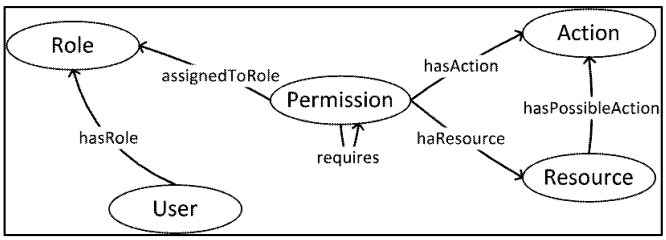


Figure 4: The access control ontology

We have worked on applying our approach in the context of the european project IMAGINE in order to make more efficient the manufacturing networks.

The access control component check inconsistencies based on the access control ontology. In order to make decisions, it may refer to an LDAP server which contains information about users and resources.

The LDAP server (IMAGINE LDAP) may needs to contact another server of a specific DMN participant in order to fulfil the request. It is also possible that the IMAGINE LDAP contacts other servers on behalf of the client application and returns the combined results after completing the operation.

The communication between the different LDAP directory is possible through the chaining mode of LDAP. In the normal case, if an LDAP server cannot return a result, it will return a reference to another LDAP server which may contain the result. This mechanism is called referrals. When the chaining mode is applied, the LDAP server has to be configured to return a complete result to the user.

The example represented in Figure 5 shows the use of the chaining mode. As shown in the figure, a central LDAP which contain two users (user1 and user2) is configured to follow referrals and return a complete result to the user. The central LDAP is connected to two other LDAP servers (Partner1 LDAP and Partner2 LDAP). Consequently, when the central LDAP receives a request that involves users registered in the other LDAPs, it will make a request and return the complete result. This method is powerful since the communication between the different LDAPs is transparent to the users.

The implementation of the access control component is based on the OASIS standard eXtensible Access Control Markup Language (XACML (Moses 2005)). XACML is a well known access control language for managing authorizations. XACML most important features are the use of attributes in policies, the possibility to extend the standard with other features, and the definition of different algorithms to combine access control decisions. XACML is an Attribute Based Access Control System since attributes associated with users, resources, and actions are considered in the access control policies. In order to meet the RBAC

requirements, a profile for the use of OASIS XACML is defined. In XACML, access control policies are evaluated by a Policy Decision Point (PDP). A Policy Enforcement Point (PEP) intercepts the user's request, transfers the request details to the PDP, and enforces the decision of the PDP. In this work we propose a PDP that makes decision and checks consistencies based on the proposed access control model. The implementation of the PDP is based on the JBoss PicketLink XACML which provides an Oasis XACML v2.0 compliant access control engine. As described in the architecture (Figure 5), the ESB transfers the request to the access control component. Therefore the ESB has the role of the PEP in the platform.

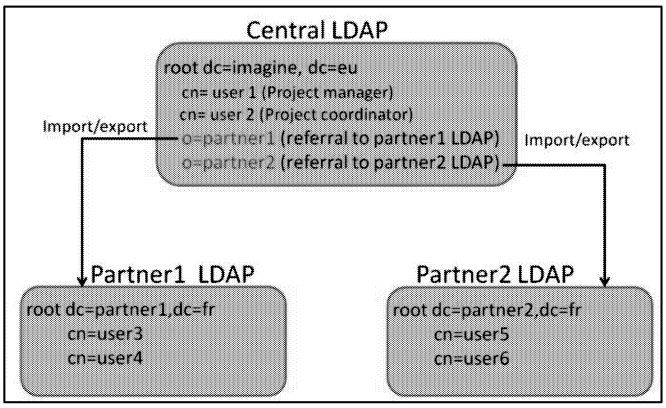


Figure 5: The access control ontology example

In order to illustrate the access control mechanism, we will refer to the presented case study. In a design phase, we assume that access control policies are defined by the authorizations administrator. These policies assign access rights to the different partners (AIRBUS, SNECMA, AIRCELLE) in the DMN. When these policies are defined in XML-based files as required in the XACML specification, the semantic model is updated in order to model the semantic relations between permissions and roles. In the execution phase, the access control component receives access requests and returns the results based on the defined access control policies through the XACML engine. For example, if a user from SNECMA requests to access to the file that contains information about AIRCELLE, then the ESB intercepts the request and transfers it to the access control component through the SOAP endpoint. Finally, the access control component returns the response to the ESB which interprets the result.

Autonomic Service Bus for performance and scalability management

The ESB is the most adapted solution to integrate distributed systems and given its role and importance, it brings up a big challenge: ensuring a high scalability and performance. Our proposal to cover this challenge is an Antonomic Service Bus (ASB). The ASB is an ESB implementing intra and extra-bus mechanisms to deal with the scalability, elasticity and multitenancy properties required by networked enterprises. It instantiates the Autonomic Computing framework proposed by IBM (IBM, 2006) for the self-management of proposed intra and extra-bus mechanisms. An autonomic manager associated to ESB will monitor its performance and will analyze it in order to identify situations asking for adaptation. A planning entity will guide the actions to be performed by the execution entity.

In this section the focus will be done on the extra-bus mechanisms for the scalability management at the IT level in an autonomic way in order to cope with pervasive systems integration. We present how using a “cloud-based” platform a networked and scalable ESB can be implemented.

The evaluation we made and the studies done in the literature allow us demonstrating the impact of the overhead on the CPU and the memory of the machine hosting the ESB (Ueno, Tatsubori, 2006). The main results of these studies are that the ESB response time, the ESB CPU and memory usage increase when we have a big throughput and a lot of mediation processes inside the ESB. Also, the maximum performance of an ESB is achieved when it uses all the resources of the host machine. In such case, it becomes a bottleneck due to a lack of physical or virtual IT resources. In this context our proposition is to avoid the ESB being a bottleneck by managing its scalability at the IT level. We talk about extra bus mechanisms because we take the ESB as a black box and our solutions consist on making elastic the physical or virtual IT resources but also switching the topology deployment mode of ESB from a single instance to a clustered or federated instances.

An ESB is a software component, commonly implemented in java and running within a java virtual machine hosted on a physical or virtual machine. Generally, tit runs on a preconfigured infrastructure with a set of specific limited resources (CPU, memory, threads, classes, etc.). When a situation with a high number of requests mediated by the ESB occurs, deployed services used to implement the business processes can become unavailable (services saturation), or the ESB, used as the connectivity and communication layer between distributed services, can become a bottleneck (ESB saturation). In this context, we dynamically apply the vertical elasticity paradigm to guarantee the scalability by monitoring the state of the ESB IT infrastructure and tuning in an autonomic way the allocated resources if needed.

The hosted machine can be a limit when it is not possible to allocate more resources to the Java Virtual Machine (JVM) instance on which runs the ESB instance. In this context, distributed and multi-instances deployment need to be done. By this way, the scalability of the ESB and so of the IMAGINE ICT platform can be managed by working on the topology of the bus deployment mode. A cluster-based deployment will be configured and the requests load will be balanced between the different nodes. The horizontal elasticity paradigm is applied, and instances will be dynamically added or removed from the cluster according to the global load (Figure 6). Clustering approach allows load balancing and sharing but has a limitation: the instances need to have identical configuration and content. This obliges services and components duplication.

Another interesting approach can be applied by taking advantage of the distributed aspect of ESBs. The proposal is to federate the ESB instances. They don’t need to have the same configuration and content. Services can be distributed and some of them migrate from one instance to others according to their performance.

The management at runtime of the ESB components is done according to a set of predefined policies. Those policies are

defined as part of the shared knowledge base that contains data providing syntax and semantic of the deployed services, but also information about the rules to be applied in order to trigger actions that implement the self-management functions and the autonomic behavior of the ASB. The next section related to the proposed Semantic Layer will talk more about this semantic part.

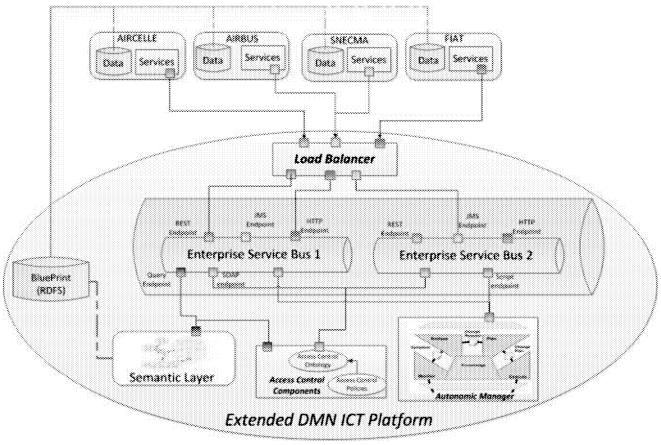


Figure 6: Extended DMN ICT Platform with clustered ESBs

Semantic Layer for data integration

Owing to the heterogeneity of the enterprises involved in this scenario, the collaboration remains a challenge. For that reason, we provide a semantic repository which integrates a unified multi-level model that describes and formalizes services and resources based on the application context. Each enterprise exposes its services to be consumed by other enterprises. A service is characterized by functional properties (what they offer) and non-functional properties (its quality of service such as capacity and response time of that service). From one hand, this semantic description is stored in a repository which is the basis of dynamic binding and discovery of services used by the ESB to match the consumer's requirements with the appropriate services. From the other hand, the role of the ESB is also to meet the contract established between consumers and providers expressing the QoS and the access control criteria. Thus, the semantic repository includes specific rules following the Service Level Agreement (SLA). As the ESB is responsible of routing the requests to the appropriate services, the process of service selection based on semantics is the following. When the ESB receives requests, it consults the semantic repository, to select the appropriate services meeting the consumer requirements. Then, the ESB refers to the access control service which in turns refers to the semantic repository that implements an ontology access control describing profiles and groups where the services are subscribed. Likewise, the ESB is enriched with the autonomic computing components to dynamically reconfigure and adapt the architecture to provide a high QoS to consumers. This depends on the resources performance, more precisely on a semantic description of IT resources such memory and CPU where the different components/services of the architecture are deployed. Each ESB can present a different configuration and resources naming. The main goal behind the semantic repository in this case is to provide a unified and detailed view to the ESB about the resources and their consumption in order to select the best configuration and allow the smooth deployment of these components with a minimal human intervention (developers, administrators or users) based on inferred rules.

VALIDATION

Set up of an Experimental Platform

Due to space limitation, only the validation of the ASB part will be presented in this section. We have deployed an experimental platform that allows modelling and evaluating ESB performance and limits. This platform can be used after to propose, develop, test and validate solutions aimed at managing ESB scalability and quality of service. The ESB Emulator is an experimental platform intended to assess ESB-based applications and systems (Figure 7). It allows simulating the behaviour of web service consumers and providers that communicate through a real ESB implementation. We use the OpenESB implementation due to its advantages in terms of JBI-conformance, smooth installation and configuration and support offered by a well-integrated IDE environment.

The ESB is deployed in a "cloud oriented infrastruture" in order to take advantage of the rapid elasticity concept of cloud computing. A virtual machine is created on a server and the capabilities of this machine are elastically provisioned.

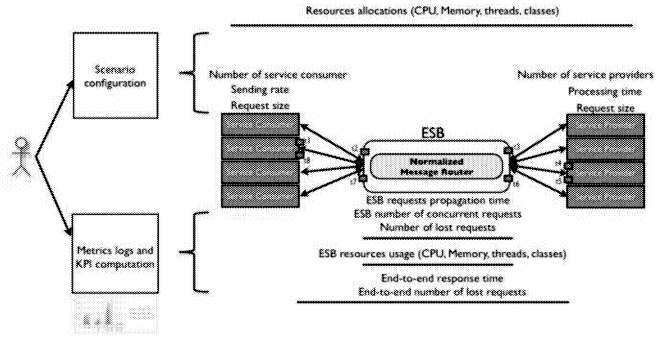


Figure 7: ESB Emulator

The ESB Emulator use cases are mainly based on two operations and the user will be able to interact with the system using a command line interface.

A "Launch scenario" operation allows a user defining a scenario. is proposed. A XML file that follows a predefined XSD format is proposed and can be used to define:

- The number of consumers
- The number of producers
- The topology he wants that refers to a set of consumer-provider interactions. The consumer will send requests to the associate provider
- The configuration of each consumer in terms of requests/seconds and exchanged request data size
- The configuration of each provider in terms of processing time and exchanged response data size
- The simulation duration

Being able to configure the scenario makes the emulator generic and allows running any type of systems integration.

A "Get results" operation allows getting all the logs. For each invocation, the consumer id, the different timestamps

(t1 to t8 on Figure 7) and the state of the java virtual machine (JVM) on which runs the ESB are stored. With all these metrics, interesting performance indicator values can be calculated. For instance:

- The end-to-end response time. It is taken as the amount of time passed since the request was sent till the reply was received
- The latency in the bus. Defined as the time the request "spends" in the ESB. If the consumer, the provider and the ESB are on the same physical machine then this KPI is quite similar to the difference between the reception of the request and the time it was sent.
- The concurrence level. The number of concurrent requests through the ESB.
- The packet loss. This is the number of the lost packets through the bus. We will consider total packet loss as well as packet loss for each consumer/provider binding.
- The ESB JVM load. With the help of Java Management eXtensions (JMX), we will be able to expose the bus for remote management of its resource consumption. These values will be correlated with the others KPIs to assert causality.

An XML file with these KPI can be retrieved. The metrics obtained using our emulator help to evaluate the performance and efficiency of an ESB.

Problem Identification

With the emulator tool we deploy a representative scenario through an ESB according to the IMAGINE project scenarios. We simulate the integration through the ESB of 4000 - 8000 - 12000 - 16000 request / response exchanges (phase 1 to phase 4 of Figure 9) to identify the limit of the ESB deployed on a cloud infrastructure with one CPU and 1GB of memory. The JMX console is used to monitor the IT resource used by the ESB. During the phase 4 we get high response times and start having request losses. This was due to the memory and the high CPU usage. The prediction or the detection of this phase 4 triggers the adaptation process and more CPU and memory will be added.

Another way to trigger the adaptation process is driven by the number of concurrent requests through the ESB. With the emulator, we add more memory and CPU to the phase 4 scenario to get the maximum of concurrent requests that the ESB can support in a configuration with one CPU and 1GB of memory (Figure 10). This number can be monitored to add more resource when we start reaching it.

Dynamic reconfiguration of Hosted CPU

An Autonomic Manager that deals with the CPU usage can evaluate the ESB resources usage during the monitoring phase. The autonomic manager monitoring entity observes both the ESB performance and the CPU of the machine hosting it. Once it measures the CPU load, it sends them to the analyzing entity. Thus, the analyzing entity computes the values and compares them to two defined thresholds (maxUsageCPUThreshold and minUsageCPUThreshold). These thresholds will guide the adaptation. When the maxUsageCPUThreshold value is reached, the analyzing entity sends a degradation alarm to the planning entitity. The optimization alarm means that the CPU usage is lower than the fixed minUsageCPUThreshold. Once the planning entity receives the alarms, it triggers an adjustment of the CPU resource. It defines the adaptation plan and sends it to the executing entity. Finally, the executing entitiy enforces the new plan that focuses on reconfiguring the virtual machine. Figure 11 gives the obtained results that show that the response time is improved by dynamically reconfiguring the CPU.

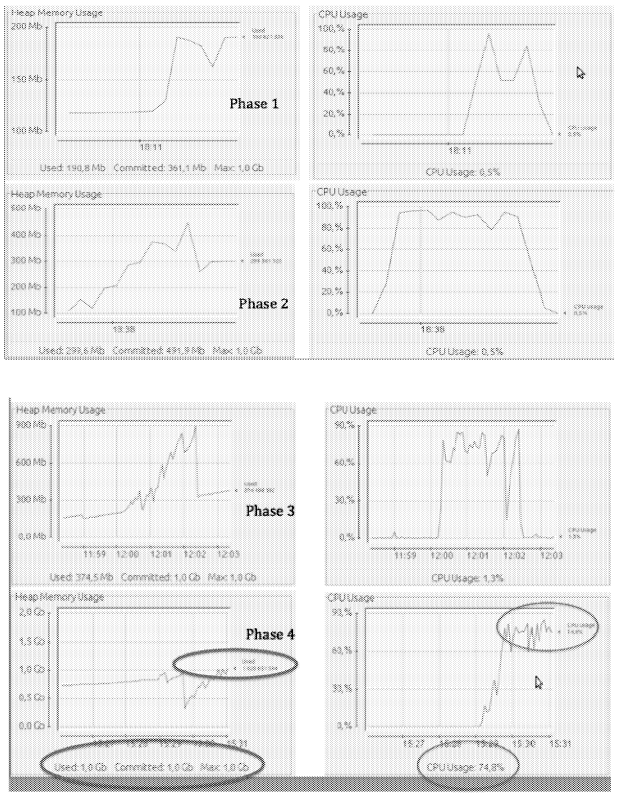


Figure 9: ESB Performance Issue

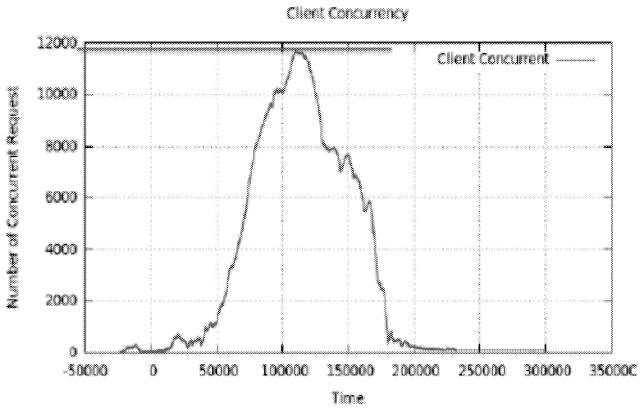


Figure 10: ESB Concurrent Requests

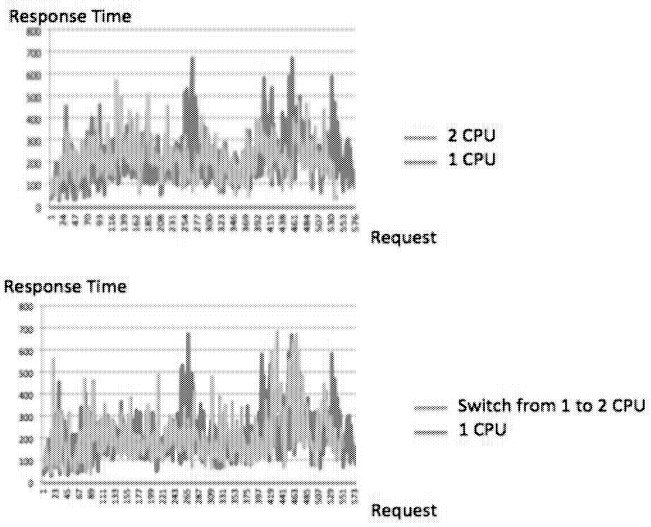


Figure 11: Response Time Comparaison for Dynamic Reconfiguration

CONCLUSION AND PERSPECTIVES

In this paper, we have introduced a new generation integration architecture well suited to satisfy the challenges of dynamic manufacturing enterprises collaborations. Problems related to semantic, interoperability, scalability and access controls when creating and dynamically reconfiguring complex networks of IT infrastructures have been presented and illustrated by the business cases targeted by the IMAGINE european project.

Based on the new generation platform provided by IMAGINE and its methodology targeting the configuration, design and management of collaborative dynamic manufacturing networks, we have propose an extension coping with the additional non functional properties related to semantics, scalability and access control.

Based on the mediation role provided by the Enterprise Service Bus considered in the IMAGINE platform, specific components aimed at deploying the adequate mechanisms to monitor, analyze and detect anomalies when dealing with these properties and the selection and enforcement of the required actions to mitigate the identified risk or faults have been designed and described.

Currently we are working on the development of these components that will be validated and integrated as extensions to the final release to the extended IMAGINE platform. Future work will be focused to the demonstration of the benefits of these solutions to cope with the new generation of dynamic manufacturing networks for collaborative enterprises.

ACKNOWLEDGEMENT

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PRINCIPLES OF AGILE SYSTEMS ENGINEERING

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KEYWORDS
Agile Principles, Systems Engineering, Mechatronics.

ABSTRACT

Due to rising competition intensity and a growing number of change requests, companies must permanently adapt to changing boundary conditions. In this contribution, proven applications of agile software engineering are analysed and transferred to entire technical systems comprising mechanical, electronical and software components. Based on transferability analysis, principles of agile systems engineering, such as self-organizing teams, cooperative leadership, incremental and iterative planning approach are derived. Principal feasibility of the agile principles is illustrated by a system engineering application scenario of ship propulsion engineering. Furthermore, resulting research and action needs are identified.

1. INTRODUCTION

Agile approach is particularly known from software engineering (cp. e.g. [Schwaber 2002]). Intention of the following contribution therefore is a feasibility study of transferring agile approach to systems engineering. Proven applications of agile software engineering are analysed concerning their transferability to entire technical systems comprising mechanical, electronical and software components. Based on transferability analysis, principles of agile systems engineering are outlined. Feasibility will be demonstrated using an application scenario of ship propulsion engineering. On this basis, an outlook on areas requiring future research is given.



Figure 1: Core Challenges

Companies are today challenged by global volatile markets giving rise to competition intensity and pressure to innovate (figure 1). The core question is who detects a customer problem first and delights the customer with a tailored innovative solution to his or her problem. In addition, mechatronic and Cyber-physical systems induce rising complexity of products, technologies and applications. Due to tightened competition, companies have to step into border areas of load carrying capacity. Also, quality requirements are continuously increasing. When integrating electronics for example, components have to be free of flitter and resist environmental conditions such as moisture, salt, heat, temperature shifts and vibration.

Companies retain only short reaction times to respond to a growing number of change requests induced by the customers during product engineering. Viewed as a whole, companies must hold a high degree of adaptability and transformation ability to be successful today. What is needed are flexibility and agility. In his evolution theory, natural scientist Charles Robert Darwin put it in a nutshell in the following way: “It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change“ [Darwin 1859].

2. AGILITY

2.1. Terminology

The adjective “agilis” derives from Latin and means “nimble” and “free to move”. “Agilitas” means speediness/ promptness. One therefore is “agile” when reacting flexibly, nimbly, actively and skilfully to the environment. According to the online economic lexicon “Onpulson”, agility means “the ability of an organisation to act flexibly, actively, adaptably and with initiative in times of change and uncertainty” [Onpulson 2013].

Strive for agility is incited by unpredictability of future. Agile approaches rely on the perception that engineering projects are too complex and too fluctuating for thorough planning down to the last detail. Project plans can be made, but they often lag behind fast moving reality. Instead, the agile approach intends to get by with as little bureaucracy and as few rules as possible. Thus freedom of action enabling prompt reactions to changing customers’ wishes is recaptured.

2.2. Origins of agility

Agile business strategies originate from production, such as "Toyota Production System" [Ohno 1988, (first published 1978 in Japanese)]. Software engineers soon discovered the potentials of agile approach and transferred core ideas to their field of application. First approaches of agile software engineering, such as Extreme Programming, are dated back about 25 years (cp. [Beck 1999]). Due to the reduction of bureaucracy and rules, agile approaches in software engineering were at the beginning nominated "lightweight".

In the last decade, agile software engineering broadly caught the world's notice. According to an empirical study of Forrester Research at the end of 2005, 14% of software producing companies in North America and Europe already applied agile processes. Another 19% were considering application of agile approach. Meanwhile, 84% of IT companies use agile methods in software engineering [VersionOne 2013].

Objective of agile software engineering is to make the software engineering process more flexible and slim than in the classical waterfall or V-model. At an experts' meeting in Utah 2001, the agile manifesto was established and the term "lightweight" was substituted by "agile" [Beck 2013]. The agile manifesto originally was meant as challenge of established project management standards. As described in [Beck 2013] it involves the aim for "better ways of developing software" by the following changes in values:

- Individuals and interactions shall be taken even more into account than processes and tools. Well-defined engineering processes and tools are evaluated as important. Nevertheless, qualification, particular needs and communication between employees are regarded as even more important.

- Working software is valued over comprehensive documentation. Although well written and complete documentation is helpful, the primary objective of engineering shall always remain, finished and applicable software.

- Customer collaboration is seen as even more important than contract negotiation. Instead of initially formulated and meanwhile obsolete technical specifications in a contract, sustained constructive and trustfull cooperation with the customer should take center stage.

- Responding to change is valued over following a plan. During an engineering project many requirements and restrictions change. Further, comprehension of the problem deepens. The team has to be able to rapidly react to such changes.

To sum up, current project management standards are still regarded as important, but the new values are prioritized even higher, when it comes to a decision (cp. [Beck 2013]).

2.3. Principles of agility

Based on transferability analysis of agile software engineering items, the following principles of agile systems engineering are derived (figure 2).

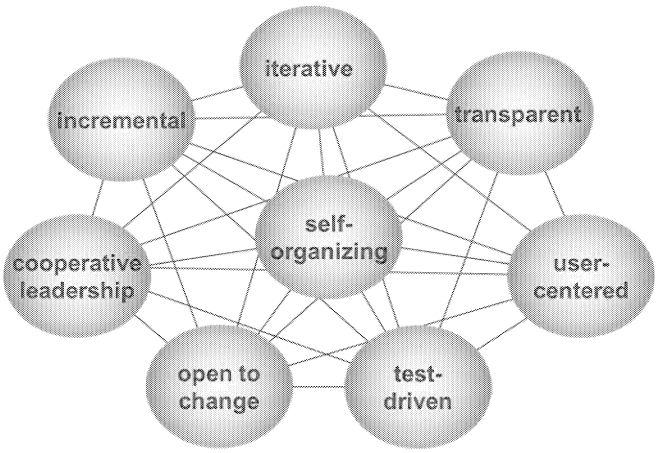


Figure 2. Principles of agile systems engineering

Self-organizing teams in terms of an intelligent swarm take center stage of agile systems engineering principles. Team members are motivated by their personal commitment to tasks. Engineers choose the most important tasks for each engineering cycle and estimate required capacities. Thus they commit themselves to self-defined goals, e.g. for the period of the next four weeks. Under ideal conditions, self-organizing teams comprise all necessary roles.

Prerequisite for realizing all other agility principles is cooperative leadership instead of authoritarian management. Control is reduced to a minimum. Leaders resist from taking corrective actions during an engineering cycle and turn from concerned into involved employees. Thus space for creativity and innovation is created.

To keep pace with increased dynamics and complexity of business processes, engineering tasks are planned incrementally and iteratively. Incremental means that engineering work is split into self-contained subtasks. During task processing no disturbances are allowed.

The iterative approach is well known from design methodology (cp. e.g. [Pahl 1996]). Engineering subtasks are processed in recursions or loops to achieve optimally coordinated development results, to increase the results gradually and to realize modifications. In a management context, iteration is an approach to deal with uncertainties and surprises in complex situations.

In addition to self commitment, transparency builds the second axis of high intrinsic motivation of involved team members. In daily coordination meetings, each team member reports on his or her work progress and any obstacles that must be cleared out of the way. Estimated capacity requirements are compared with the capacity actually used.

User-centered development means permanent focus on customer benefits. The development team recognizes the problem of the customer and thrills the customer by the fact that he or she receives a solution to this in the short term. User stories direct system engineering on added value experienced by the customer. Customers continuously receive already completed and audited interim results of the overall development.

Test-driven development means that first the testing format is set, and then modules are developed. Thus on the one hand only those modules are delivered to the customer, which are confirmed in their functionality. On the other hand, a so-called "over-engineering" is avoided, because it is always clear when the task is finished.

Change requests introduced by the customer during development process are welcomed and used as competitive advantage of the customer. Actual customer position is determined between two development cycles. Needed supplements as well as necessary changes are revealed and considered in the forthcoming development cycle.

With the help of the above decribed principles of agile system engineering, concentration is directed back to the basics: innovation and focus on customer value. For this, values are more strongly focused on cooperation of engineers, direct communication, results orientation and rapid feedback. Processes and tools may not be missing, but fade into the background.

3. APPLICATION TO SYSTEM ENGINEERING

Principal feasibility of the above described principles is illustrated by a system engineering application scenario of ship propulsion engineering. As product example, the Voith Schneider Propeller is taken.

3.1. Application scenario

Voith Schneider propeller is among the world's ship propulsion systems an embodiment of agility. Within just five seconds it switches from full headway, for example, to full reverse. Any thrust direction is continuously selectable between 0 and 360 degrees. The Voith Schneider propeller incorporates not only a propulsion, but also a rudder function. Its action principle is based on complex slider-crank kinematics deflecting the propeller wings (figure 3). Thus an extremely accurate and powerful drive and rudder function is realized (cp. e.g. [Jürgens 2002]). Some of the main fields of application are Voith water tractors, double-ended ferries and platform supply vessels. As application scenario, system engineering of a Voith Schneider propeller for an offshore windpark supply vessel is chosen.

3.2. Cooperative leadership

Agile principles can only be realized, if leadership structures are cooperative instead of authoritarian. This means to gradually replace control by confidence and let a new management culture grow. Control is thus reduced to the minimum. According to a Kienbaum study by Rolf Berth, companies which rely on a culture of trust with little control, generate returns 162% higher than their competitors [Berth 2006].

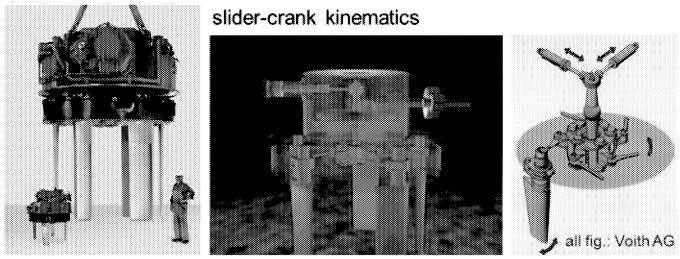


Figure 3. Application scenario Voith Schneider propeller

Corrective actions are only taken in between two engineering cycles. A development cycle in agile systems engineering takes about 8 weeks to 3 months. There are no interventions nor disturbances during a running engineering cycle.

Cooperative leaders turn concerned employees into involved ones. Classical superiors decide on what to do. German managers even like to add how to do this, which scheme or which tools to use. Nevertheless, key motivation for agile teams is the answer to the "why?"-question. Everything else is then obtained by itself. Thus space for creativity and innovation is created. Moreover, cooperative leaders are responsible for balanced capacity loads and a clear framework within which the actors can move freely.

3.3. User stories

Starting from user stories, the way for a user-centered development is paved. Instead of requirement specifications, so-called "user stories" are formulated to define the desired output from the customer's perspective. Beyond mere customer demands, emphasis of user stories lies on underlying motivation of the customer. For this reason, the customer's role is examined and documented in a user story. User stories are formulated in everyday language and deliberately kept short. They typically comprise not more than two sentences (cp. e.g. [Schwaber 2002]). In agile software development, such as Extreme Programming (XP) or Scrum, typically three questions are answered by the user story [Hruschka 2009]:

- "Who?"
- "What?" and
- "Why?"

In the proposed application scenario, base development is described by an operator of an offshore wind farm who

would like to run and maintain his or her wind turbines at each swell, in order to minimize costly downtime (figure 4).

To further clarify the development goal from a systems engineering point of view, the classical user story structure is enhanced by the following aspects:

- "Where?"
- "How?"
- "In contrast to"

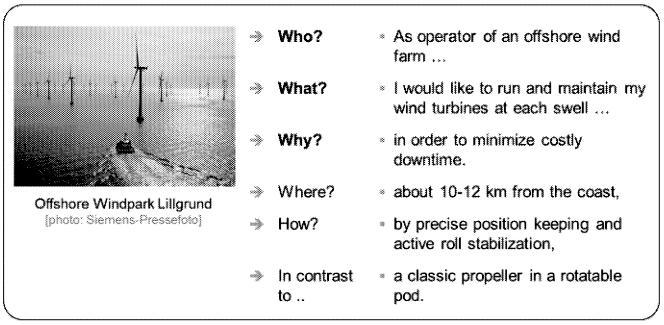


Figure 4. User story base development

Hence the customer's motivation is decribed more precisely and first ideas about the realization are collected. In order to deepen understanding, the envisioned approach is contrasted against standard solutions. In the proposed application scenario, the wish for precise position keeping and active roll stabilization justifies the cost of a Voith Schneider propeller.

The principles of user-centered development and welcoming change requests become obvious, when a new user story is added in between two development cycles (figure 5). An owner of offshore windpark supply vessels has ordered a Voith Schneider propeller for a new supply vessel. During ongoing propeller engineering project, he finds out that markets of offshore windpark installation and maintenance are rising faster than expected. If he could take the planned platform supply vessel earlier into operation than initially planned, he could acquire additional orders from his customers. He expresses his change request towards propeller engineering. His wish is welcomed by the agile engineering team and realized promptly in order to improve the customer's competitive situation. However, the self-organizing team has to skip another user story in order to still keep the time line. In coordination with the customer an agreement is made upon skipping the planned optimization of the propeller's wing shape. The customer can earn much more profit when taking a new vessel earlier into operation than he ever could with fuel saving due to wing shape optimization. Therefore connection to a different engine is calculated and drafted in the forthcoming development cycle. The proposed application scenario also illustrates, how important the user story is to control an agile project.

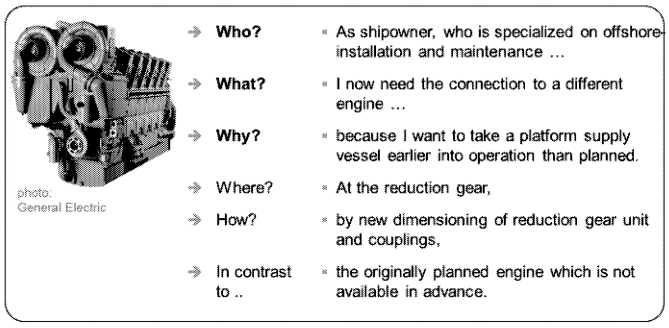


Figure 5. User story engineering project

3.4. Iterative and incremental planning

Agile systems engineering responds to the growing dynamics and complexity of development projects by not pre-planning everything to the last detail. Instead, there is an open learning process. The planning is done iteratively and incrementally, and is performed on the responsibility of the development team. The agile team meets once before the beginning of an engineering cycle for a period of about half a day. In this meeting, team members select the most important and urgent user stories for the next engineering cycle. Chosen user stories are collected in the so-called "sprint backlog" (figure 6). Each respective responsible developer estimates his or her effort to implement the assigned user stories. Thus team members fully obligate themselves to their tasks and are highly motivated to realize them in time.

Each day, the agile team meets for 15-minute coordination meetings. Each team member briefly reports on his or her work progress and capacity consumption. Thus, everybody is always informed about each other's progress of work and actual plans. Daily transparency about contents and timing promotes commitment and trains each team member in effort estimation.

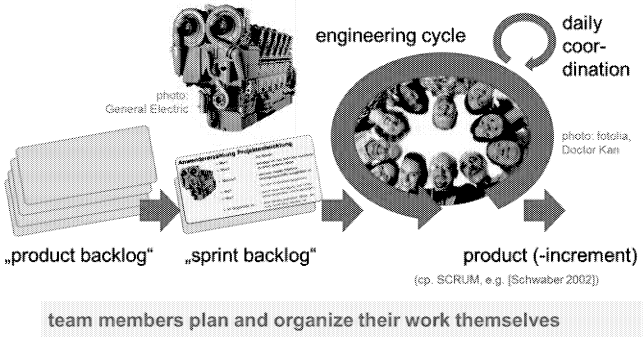


Figure 6. Iterative and incremental planning

The customer is continuously involved in the development process by regular result presentations at the end of each engineering cycle. Together with the customer, results are analyzed and evaluated. Team members receive direct feedback on customer acceptance of the results. Necessary adaptations are identified at an early stage. Figure 6 illustrates the above mentioned application scenario of a necessary connection to a different engine. The user story "optimizing wing shape" is substituted by the new user story

"engineering project". The fact, that the customer can actively interfere and prioritize requirements according to actual competitive situation prevents that product functions are realized which do not meet the user's needs or find only little attention. Together with the customer, costs are opposed to benefits of intermediate results. Thus it is ensured that results are worth the effort.

3.5. Test-driven engineering

Following a classical approach, such as waterfall or V-model, tests are being developed in parallel to the system itself. The developer already knows the system, before the test scenario is defined. So-called "white-box tests" can cause a certain kind of "blindness" and test around errors.

In test-driven engineering, the testing format is specified, before development of particular user story is started ("grey-box testing"). Only in their functionality confirmed product increments are delivered to the customer. This way, the entire development is incrementally driven by the immediate feedback of specific tests. No more or less than what the customer requires, is developed. In system engineering, numerical calculations, simulations and digital mock-ups are particularly appropriate means of test-driven approaches. An example of simulation based optimization of body is given in figure 7. Essential for the propulsion of a marine engine is an optimum matching between the contour of ship body and the flow of the propeller. This is evaluated both on the basis of numerical calculations and simulations as well as on classic trials in the scaled-down model in a circulation tank, as shown in figure 8.

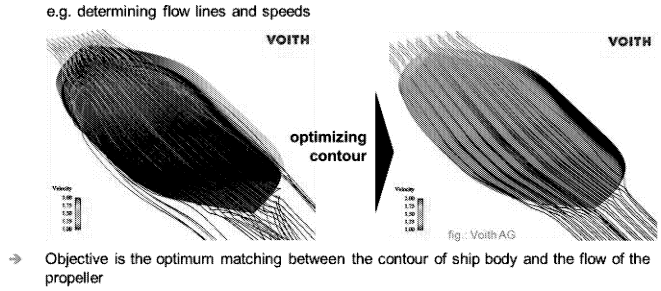


Figure 7. Simulation based optimization of body

Thus, functional fulfillment is checked and secured parallel to the development and prior to delivery to the customer. For basic developments, tests are not only carried out on the model, but also as test runs under real conditions.

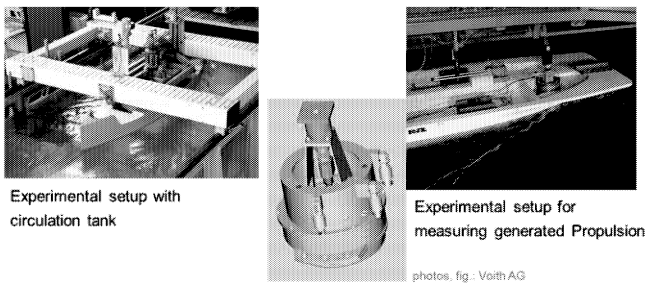


Figure 8. Model based experiments

A test-driven approach results in the tendency towards modular product structures, which are easier to modify and extend. From the engineer's point of view, the planned mechatronic system is generated by small increments being developed and tested independently from each other.

4. SUMMARY AND FUTURE PROSPECTS

In response to growing product complexity and dynamics of markets, companies strive for more agility. On the basis of the origins of agile business approaches, transferability to systems engineering was analysed in this contribution. As a result, principles of agile systems engineering were deduced. Applicability of principles was illustrated using a complex ship propulsion scenario as an example. The higher the project's degree of innovation and the associated uncertainties, risks and complexity, the more likely the chance is that a project using agile methods can be brought to a successful conclusion. Limits of applicability are drawn by regulatory requirements, such as quality audits. In order to meet such requirements in an agile project, two or three engineering cycles have to be spent exclusively on generating the required documentation.

Various research and action needs result from the findings of this feasibility study. The following areas require future research:

- Modularization approaches: Suitable modularization approaches have to be found, which support breaking down the overall development task into increments as far as possible independent from one another. For this purpose, applicability and benefit of modularization approaches of variant and complexity management have to be checked.

- Test-driven development: simulations based on understood cause-effect relationships and testing of models with realistic test specifications, such as load profiles and time scaling factors

- "Good practices" for agile system development: To provide a guide for agile systems engineering, suitable agile practices must be developed and tested in the application context. This toolbox can then be made available to producing companies which want to step into agile systems engineering.

For broad industrial application, managers have to be convinced about the advantages of agile systems engineering. As a prerequisite, the potential benefit has to be quantified.

As further need for action, the findings have to be integrated into models and methods of mechatronic systems engineering and innovation management, such as VDI guideline 2206 "Design methodology for mechatronic systems" [VDI 2206].

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BIOGRAPHY

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CONCURRENT ENGINEERING DESIGN

REVERSE ENGINEERING FOR THE UTILIZATION OF PRODUCT MODEL DATA FOR CAX WORKFLOWS IN DENTAL TECHNOLOGY

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KEYWORDS
Reverse Engineering, Digital Dental Workflow, Geometry Repatriation, CAx, Virtual Validation.

ABSTRACT

Increasing cost pressure and shorter innovation cycles require an optimized dental product development process. The fast progress in the field of virtual product creation enables the application of powerful computer aided tools for modeling, simulation and manufacturing. Increasing digitalization leads to virtual representation of products and concerning processes. Current CAD systems enable the creation of dental 3D models, but fall short to utilize approved CAx methods for simulation of the digital dental workflow.
In this paper the application of Reverse Engineering in the digital dental workflow is analyzed. As part of the analysis geometry repatriation is performed in two different CAD systems. A dental bridge and a patient's jaw serve as validation objects. Main target is the creation and utilization of processable, integrated dental 3D CAD models. These integrated dental models can be used for manufacturing, but they rather enable the virtual validation of dental products through the application of finite element analysis and multi body simulation. This leads to an optimized dental product development with cost savings, quality improvement, and a shorter time to market. Furthermore, opportunities for improvement of the digital dental workflow are identified and exemplarily demonstrated.

INTRODUCTION

Dentistry is subject to a profound change. Besides new materials and manufacturing processes, computer aided technologies are becoming more and more important. Increasing cost pressure and shorter time to market demand efficient methods and tools to support dental product development. Ideally, most activities and processes are represented in the virtual world.

The digital dental workflow describes the process to manufacture dental products based on CAD/CAM technology. The digital dental workflow is characterized by a high complexity and interdisciplinarity. Different participants like dentists, dental laboratories, and dental manufactures are involved. Main challenge is the provision of a patient individual production at a price of mass production. For every single job an individual development and manufacturing process have to be performed. To stay competitive the workflow must be economic and has to be supported by state of the art technologies (Heister and Anderl 2013).

Reverse Engineering supports the digital dental workflow as a methodical approach to digitalize real, physical dental products, but also to convert patient's oral cavity into virtual 3D CAD models. This 3D CAD models can be used for analyses, simulations, quality control and manufacturing. The digitalization of products is usually performed by the use of 3D scanners and the scan data is stored in STL files. Depending on the achievable quality of the 3D scanner and the selected scan performance the results of the scan data can vary. Geometry repatriation is conducted on the basis of the STL files and leads to 3D CAD models. Although there already exist several methods for geometry repatriation of volume models, no method was able to prevail in dental technology and the implementation differs in the various CAD systems.

Because of the cost-effectiveness and resource savings through digitalization Reverse Engineering based on surface models is already established in dental product development. Although a number of approaches and concepts have already been developed there is still a need for computer-aided methods and tools to support the digital dental workflow. Especially the utilization of processable 3D CAD models paves the way for integrated models, which can be used for downstream processes. These integrated models enable the virtual validation and optimization of dental products by the

application of approved methods, e. g. finite element analysis and multi body simulation.

In this paper the application of Reverse Engineering in the digital dental workflow is analyzed with focus on geometry repatriation of volume models. The geometry repatriation is based on STL files and is performed in two CAD systems, NX 8.5 and CATIA V5. A dental bridge and a patient's jaw serve as validation objects. Main objective is the creation of processable, integrated 3D CAD models. These integrated models enable the optimization of the dental bridge in a patient's oral situation and are used for the manufacturing process.

RELATED WORK

Reverse Engineering

Reverse Engineering describes a method for the transfer of real objects into their virtual representation. Based on the virtual representation additional engineering processes can be applied. Starting point of the reverse engineering process is a physical part. The part is digitalized by the use of a 3D scanner. The output is a point could. A point cloud depends on a collection of 0D elements which represents points on a surface. To get a surface representation the 0D elements must be transformed into 2D elements by application of the Delaunay triangulation. This triangulation method ensures a maximization of inner angles of all triangles (Chen et al. 1999; Lee et al. 2002). As output a mesh of 2D triangles in a 3D element space result. The corresponding data format is the STL file. Another possibility of extracting a surface model is a NURBS (Non-Uniform Rational B-Spline) representation instead of triangles (Piegl and Tiller 1997; Wang 2010). After getting a surface model the dental reconstruction can start based on the virtual representation of patient's jaw.

STL Format

STL stands for Standard Tesselation Language and provides a standardized interface for the digital dental workflow. The STL format serves as data format for the transfer of geometry information between geometry capture and geometry repatriation. STL files contain a triangulated description of the object surface in form of a point cloud. Each triangle (facet) is defined by three vertices and a normal vector, see Figure 1. For each vertex three coordinates are stored (Szilvasi-Nagy and Matyasi 2003).

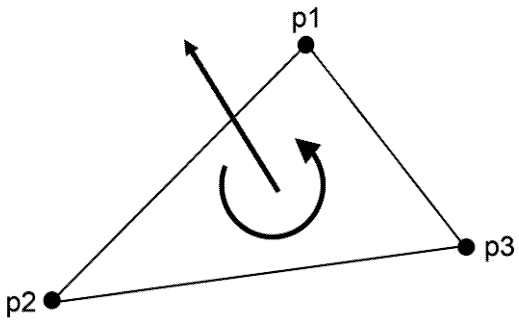


Figure 1: Facet of a STL file (Chen et al. 1999)

Facets in STL files are constructed according to two rules. First, each facet has two common vertices with neighboring facets. Thus, no vertex can be on the edge of an adjacent facet. Secondly, the object surface is approximated by facets, which define the demarcation of an object from its environment. The normal vector of a facet points outward, away from the material side. The vertices are arranged counterclockwise (Chen et al. 1999).

Methods of Geometry Repatriation

There are different methods for geometry repatriation from the information contained in point clouds respectively STL files. They can be divided into methods based on regular geometry and free-form elements (Elias 2012). Approaches for geometry repatriation from technical drawings are not taken into consideration, as they do not use point clouds as input. Existing methods can be classified according to the type of underlying point data. Advanced methods of digitalization capture additional information, such as neighborhood relations and references of the object topology. However, most methods are based on unstructured point clouds. Although the procedure is more difficult on the one hand, on the other hand these methods can be applied more generally and allow a higher flexibility (Anokhin 2013).

For unstructured point clouds some preparations are necessary in order to enable the geometry repatriation. Especially the determination of neighborhood relations plays a major role. There is a variety of methods (Anokhin 2013). Erbas uses for the management of points a k-dimensional-tree structure (in this spatial case k=3). Here, the point cloud is divided by planes in areas, what simplifies the search for neighborhood relations (Erbas 2012). Another method is based on a grid procedure. A bounding box is put around the point cloud in order to divide the point cloud into cubes, which contain the single points. For the search of neighborhood relations, only adjacent cubes have to be analyzed. Many cubes contain no points, since they are located in the inner of the object. Therefore it is useful to connect the grid procedure with hash tables (Schuhmann 2004). Wilke defines general

requirements for the data structure of large point clouds and uses a cube octree structure (Wilke 2002).

When the neighborhood relations are defined, they represent local approximations of the object surface, from which further information for geometry repatriation can be obtained. Usually normal vectors and local curvature values are determined. With this information, the point cloud is divided into areas or edges and guidelines are derived. As a result single surface segments and simple geometry elements like volume primitives can be created (Anokhin 2013).

There are many other methods for geometry repatriation. Reference is hereby made to important contributions, see also (Hoppe et al. 1992; Knorpp 1998; Vanco 2002; Weber 2011; Beniere 2013). Most of these methods originate from the fields of mathematics and computer science. Often they describe only abstract concepts with a very limited implementation. Especially the linkage to current CAD systems is missing. Although the utilization of methods to create processable 3D CAD models for the digital dental workflow have a huge potential, none of them have been applied in dental technology yet. In this paper a solution for the creation and reuse of fully functional dental 3D models is introduced.

Geometrical Representation

The geometrical representation of elements can be classified in two dimensions: dimensionality of the element space and dimensionality of geometry elements, see Figure 2. The CAD/CAM technology in dental context is based on surface models for the virtual representation of patient's jaw as well as the restoration. This surface model depends on 2D elements (triangles) in a 3D element space. A volume model, based on 3D elements, has not been applied in the digital dental workflow yet.

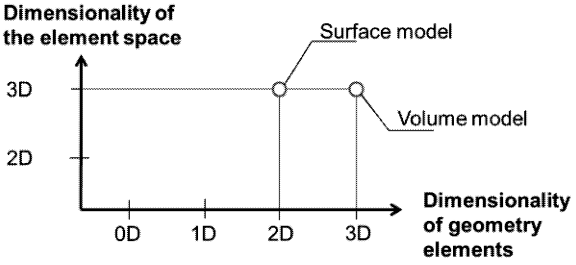


Figure 2: Dimensionality of element space and geometry elements (Anderl 2013)

Volume Models

Volume models (or solid models) enable the complete description of geometric volumes and the definition of bodies in combination with a material designator. The various types of volume models show differences in the data structure of their computer internal representation. Volume models are divided into three groups (Anderl 2013):

- Generative volume models
- Accumulative volume models
- Hybrid volume models

Common representatives of generative volume models are constructive solid geometry (CSG) models, sweep models and feature models. Boundary representation (B-Rep) models, binary cell models and finite element (FE) models are among accumulative volume models. Hybrid volume models combine different representations and consist of two data structures. Usually they have a primary generative data structure and a secondary accumulative data structure. B-Rep models are among the most important volume models in current CAD systems (Anderl 2013).

CONCEPT

Today's digital dental workflow contains the steps 3D scanning, CAD modelling, NC programming, and manufacturing, see Figure 3. The patient's oral situation is captured with an intra or extra oral 3D scanner. The resulting STL file is used as basis for CAD modelling. The process leads from a real patient's oral situation to its virtual representation in form of a surface CAD model. By the application of CAD/CAM technology NC program code is derived from the surface CAD model and the manufacturing process is initiated.

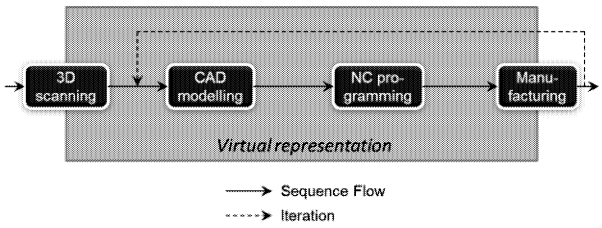


Figure 3: Present digital dental workflow

The digital dental workflow describes an idealized process. Today, the single processes are often not formalized in this way and match insufficiently with each other. The inadequate definition of interfaces is also an issue. Although the derivation of manufacturing information and NC program code from CAD models has already been established, there is still a need for approved computer aided methods and tools for virtual validation and simulation. On the one hand, this is partly due to insufficient geometry repatriation and the manner dental CAD models are created. Especially the information contained in STL files is not properly utilized. On the other hand, it is justified by the application of highly specialized software, which prevents a suitable integration. The development of an

integrated solution is part of current research in dental technology.

In this paper a new methodical approach for the utilization of integrated dental 3D CAD models is introduced. The approach extends the present digital dental workflow as it enables finite element analyses, multi body simulations and tolerance studies. The virtual validation of dental products leads to an optimization of the dental product development process with cost savings, time savings and quality improvement. By the application of computer aided analyses failures can be identified and repaired in early stages. Moreover, waste production is reduced, resulting in material savings and a reduction of required processing steps in manufacturing. Figure 4 shows the extended digital dental workflow.

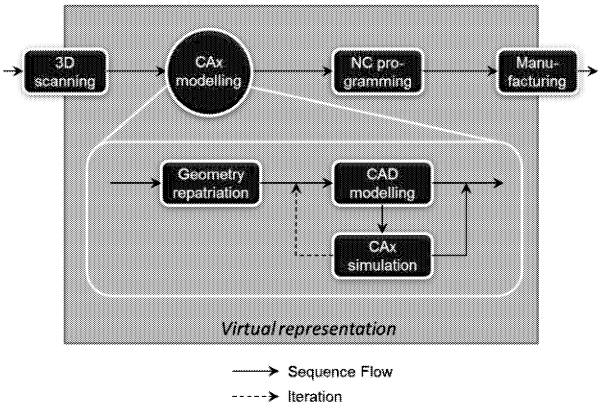


Figure 4: Extended digital dental workflow

The main difference to the present digital dental workflow is the improved geometry repatriation, which enables the creation of volume models and the utilization of established simulation tools. This changes the second step of the digital dental workflow from basic CAD modelling to advanced CAx modelling. The methodical approach is described in the following.

Geometry Repatriation

The patient's oral situation is captured with an intra-oral 3D scanner. The scan data is stored in STL files. STL files contain a triangulated representation of the oral situation. Each triangle (facet) is clearly described by three vertices and a normal vector. Based on STL files a 3D CAD model is created. Here, a surface model is not sufficient, a volume model is needed. Only a volume model enables the subsequent processing in the CAD environment and can be used for downstream CAx processes. The process of geometry repatriation has to be considered form the input side (STL file) and the output side (volume model).

Depending on the used CAD system the process of geometry repatriation varies and possibly additional software is necessary. Geometry repatriation is divided into two steps:

- Surface reconstruction
- Volume repatriation

Surface reconstruction can be progressed in two different ways. The first approach is the creation of geometric triangles based on the facets of the STL files. Either the facets are directly converted into triangles or triangles are reconstructed by the creation of lines between vertices, which represent triangle edges. The total surface results from the sum of all triangular surfaces (Anokhin 2013). The second approach uses a mathematical description of the surface based on non-uniform rational B-Splines (NURBS). NURBS are mathematically defined curves and surfaces that enable the modeling of any shape. Both the approximation and interpolation of vertices is possible. In principle, any shape can be created with NURBS. The surface is created piecewise by functionally defined geometry elements. Once the surface is closed, the volume model can be created. Therefore specific functions are available in CAD systems. Often the creation of the volume model is done automatically, when the total surface of an object is closed.

Despite the existing approaches for geometry repatriation, the process itself is often not formalized and has not been applied to dental technology on the basis of volume models. The different implementation in current CAD systems leads to highly specialized software tools. This prevents the reuse of dental CAD models and the further processing in approved CAx processes. The approach presented in this paper is a first step towards an integrated solution.

3D CAD Model and CAx Workflows

The geometry repatriation transfers the geometry information contained in STL files into fully functional 3D CAD models. These dental 3D CAD models enable the reuse of product model data and the integration of knowledge from different life cycle domains. Moreover, they can be used in all downstream CAx processes. Finite element analyses of dental products as well as multi body simulations and tolerance studies of patient's oral situation can be performed in a virtual environment, see Figure 5.

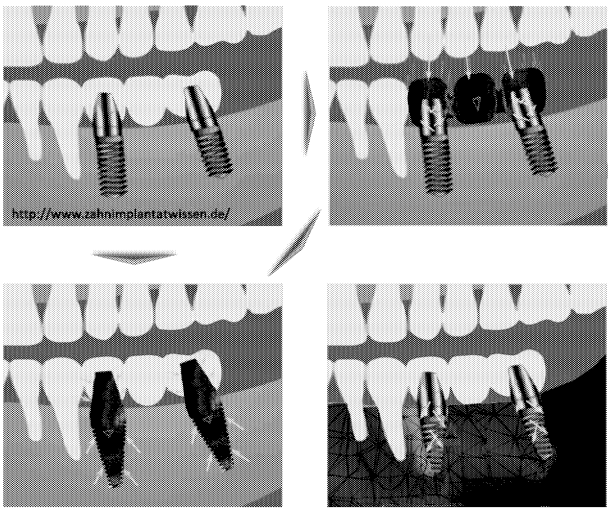


Figure 5: Exemplary use case of a finite element analysis

Finite element analyses enable the calculation of mechanical properties, like stresses and displacements. This allows the patient individual design of dentures, analyses of the interaction between dentures and patients jaws as well as chewing simulations. Multi body simulations are used for motion sequences. Especially assembly simulations of multi-unit dental restorations, based on preparations with large angular deviation, show a high potential. Today, there are big gaps in restorations in order to ensure the insertion. In future, these gaps can be reduced to a minimum due to multi body simulations.
The virtual validation saves time, reduces cost and increases quality. All this haven't been possible with previous dental surface CAD models, due to an inferior geometry repatriation. The most important advantage of the introduced approach is the implementation of detailed analyses and simulations of patient's oral situations and dental products. In contrast to the present digital dental workflow, which only represents a sequential process, the extended digital dental workflow allows the integration of optimization loops, based on fully functional 3D models. After the virtual validation, the dental products are manufactured.

Manufacturing

Based on dental 3D CAD models manufacturing information and machining code is derived. Typical manufacturing processes in dental technology are milling and additive manufacturing, like selective laser sintering. Therefore, highly specialized production facilities have been developed. Due to the virtual validation dental products can be manufactured precisely. Costly reworking in dental laboratory is reduced to a minimum. This is a major step towards a patient specific mass production.

In rapid manufacturing physical dental products are manufactured based on surface CAD models. Rapid manufacturing contains conventional manufacturing processes like milling as well as additive manufacturing processes. Besides testing and validation rapid manufacturing enables the economic manufacturing of dental products. Dental crowns, abutments, veneers and bridges can be manufactured resource-efficient and in a short time. This saves valuable manufacturing time. In addition, additive manufacturing machines, e. g. for selective laser sintering, are becoming more favorable.

PROTOTYPICAL IMPLEMENTATION

For the prototypical implementation STL files of a dental bridge and a patient's jaw serve as input. The process of geometry repatriation is performed in the CAD systems NX 8.5 and CATIA V5. The resulting dental 3D CAD models are used for a finite element analysis as part of the virtual validation.

Geometry Repatriation in NX

The geometry repatriation in NX 8.5 is divided into two steps: surface reconstruction and volume repatriation. For surface reconstruction in NX 8.5 an additional software is necessary, Rhinoceros 5. The Rhinoceros 5 software enables the import of STL files and the visualization of the contained point cloud. Based on NURBS description the point cloud is transformed into a polysurface. This polysurface is then exported as STEP file (Beisner et al. 2013). STEP (Standard for the Exchange of Product model data) is a series of standards for the description of product data. Due to the standardization and a CAD neutral description it is suitable for the exchange of product data between different systems (Anderl and Trippner 2000).

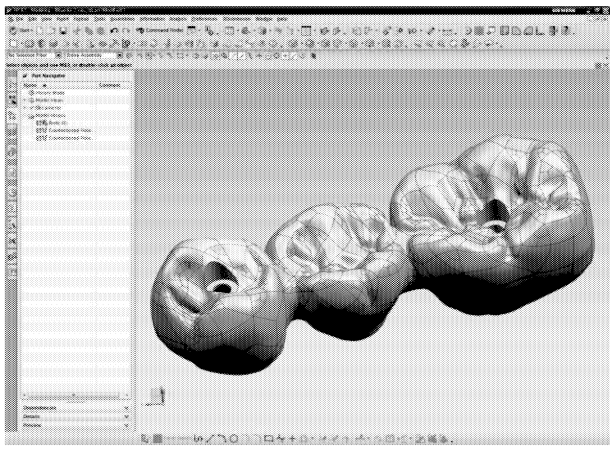


Figure 6: Geometry repatriation in NX 8.5

The model only consists of a surface, which is hollow inside. In addition, the surface is often not closed. A further processing is not possible with this model. For the creation of a processable dental 3D CAD model a volume model has to be generated in the second step. Therefore, the STEP file is imported in NX. With cutting planes the surface model is trimmed. The resulting cut surfaces are used to close the surface of

the model. Through the sew-function the individual single surfaces are united to the closed total surface. After this operation, a volume model is automatically generated from the closed total surface, which can be used for subsequent processing steps. As an example the application of holes to the dental bridge is demonstrated Figure 6. If the volume model is not generated automatically, this can be realized through the export of the model as a STEP file (Beisner et al. 2013). The process of closing the total surface can be time-consuming, but the introduced approach for geometry repatriation shows the feasibility in current CAD systems and is very suitable for an automation.

Geometry Repatriation in CATIA

The geometry repatriation in CATIA V5 starts with the creation of a new part. The user has to change the workbench from part design to the workbench digitalized shape editor. Afterwards the import function for a STL file has to be applied. Subsequently the load operation appears in the history tree of CATIA V5, see Figure 7. The next step is to create a mesh. The transformation from STL into a mesh representation is needed to define the neighborhood relations of contained geometrical elements, like points, edges, and faces. CATIA needs the topological information to process the geometrical information with additional features. Next step of the geometry repatriation process is the creation of a NURBS surface. Various parameters define the accuracy respectively the deviation between the geometrical representation as STL model and NURBS model. Important parameters are for example mean surface deviation and surface detail. Afterwards a NURBS surface model results. If the NURBS surface model is fully closed, a feature creates the volume due to surface boundaries. With this, the geometrical representation is repatriated into a native CATIA part file. Hence, every conventional feature of CATIA can be used. Also the transformation into a STEP file is possible to utilize other CAx workflows.

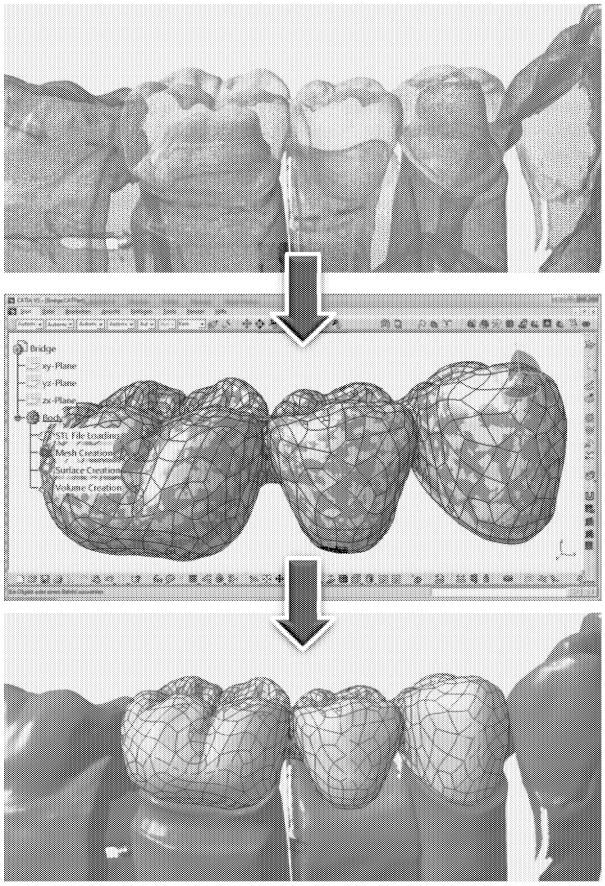


Figure 7: Geometry repatriation in CATIA V5

Demonstration of a CAx Simulation

As already mentioned, a STEP file can be used as output of geometry repatriation in NX and CATIA. With this approach, other CAx workflows can be utilized. As demonstration of a CAx workflow a finite element analysis is applied. The STEP file has to be imported in a FE simulation software tool. As demonstration object the repatriated dental bridge is used. The inner stress of the dental bridge can be calculated both in an isolated manner and in context of an assembly with the patient's jaw. For the demonstration the bridge is simulated without assembly context. After importing the dental bridge, a material has to be defined as first step of the pre-processing. Then a mesh has to be created. Therefore the volume model is transformed into a tetrahedron representation. Next step is the definition of constraints and loads. Then the van Mises stresses can be calculated. After solving, the inner stresses can be visualized in the post-processing, see Figure 8.

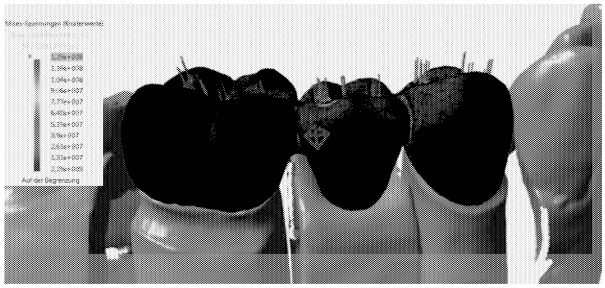


Figure 8: Finite element analysis

The prototypical implementation of a FE simulation shows the capability of the new approach for geometry repatriation in dental technology. But some difficulties impede a smooth utilization. If the STL file is not fully closed, a NURBS as well as volume repatriation requires a high effort. In case of a successful volume repatriation other difficulties in FE simulation can arise. Sometimes it is difficult to transform the volume into a tetrahedron representation. The reason is an inadequate combination of parameters like the size of tetrahedrons. Therefore, a valid combination of parameters has to be defined in an iterative manner to proceed the FE simulation.

CONCLUSION AND OUTLOOK

In dentistry computer-aided methods and tools are becoming more and more prevalent. This leads to the virtual representation of dental products and workflows. The present digital dental workflow enables the creation of 3D models, but only as surface models. This is sufficient for manufacturing, but prevents the utilization of approved computer-aided technologies for a virtual validation of dental products. Reverse Engineering describes a methodical approach for the digitalization of objects. The integration of methods from Reverse Engineering based on volume models in the digital dental workflow offers a huge development potential for established CAx workflows.

In this paper an approach for the creation of fully functional and processable dental 3D CAD models is introduced. Based on STL files volume models are generated through an advanced geometry repatriation. These dental 3D CAD models enable the reuse of product model data and knowledge integration. They can also be used for approved CAx workflows, like finite element analysis and multi body simulation. The applicability of the concept is demonstrated in two different CAD systems, NX 8.5 and CATIA V5.

The virtual validation reduces unnecessary and large span iteration cycles to a minimum. This results in cost savings, shorter processing time and quality improvement. The implementation of processable dental 3D CAD models and their application in virtual validation is a major step towards a patient individual mass production of dental products with an improved process reliability.

This paper shows the needs of further basic research. CAx workflows of mechanical engineering are optimized for objects with regular geometries. Usually simplifications of FE models are applied, but in the dental technology a highly precise representation is needed to enable valid simulations. Common calculation algorithms are often not optimized for small-scale anatomic structures.

This contribution is a first step to establish processable 3D CAD models in dental technology. Key elements are the reusability of dental product model data and the integration of a virtual validation into the digital dental workflow. In order to achieve an improvement for virtual validation, existing methods for the calculation and simulation of dental products have to be analyzed and adapted to the requirements of dental technology. Future research will concentrate on the development of methods and tools for a further integration of dental 3D CAD models. On the one hand the process of geometry repatriation must be improved and an integration of voxel models based on CT scans is desirable. On the other hand repetitive tasks, which are often performed manually, have to be automated. The long-term aim should be to develop an integrated dental product data model.

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CONCURRENT ENGINEERING IN ARTICULATED STEER VEHICLE DESIGN

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KEYWORDS

Concurrent engineering, articulated steer vehicle, modeling, simulation, identification

ABSTRACT

Concurrent engineering is a work methodology based on the parallelization of tasks. The idea is that the concurrent nature of these processes significantly increases productivity and product quality. This way, errors and redesigns can be discovered early in the design process when the project is still flexible.
Mechatronics is emerging as a concurrent engineering thinking framework in the process of designing complex machines. Both control system development and mechanical system development adopt the so-called "V - approach", propagating system level requirements to component design.
An off-road vehicle is considered as being any type of vehicle, which is capable of driving on and off paved or gravel surface. It is generally characterized by having large tires with deep, open treads, a flexible suspension, or even caterpillar tracks. The introduction of articulated frame steering was a landmark in the development of off-road vehicles, especially for loading and earth-moving applications. This paper presents an application on modeling and simulation of the steering system for an articulated wheel loader. The purposes of this study are to develop the simulation using AMESim code and to obtain the best design structure and parameters of the steering valve.

INTRODUCTION

Concurrent engineering is a work methodology based on the parallelization of tasks (i.e. performing tasks concurrently). It refers to an approach used in product development in which functions of design engineering, manufacturing engineering and other functions are integrated to reduce the elapsed time required to bring a new product to the market.
The basic premise for concurrent engineering revolves around two concepts. The first is the idea that all elements of a product's life-cycle, from functionality, predictability, assembly, testability, maintenance issues, environmental impact and finally disposal and recycling, should be taken into careful consideration in the early design phases.
The second concept is that the preceding design activities should all be occurring at the same time, i.e., concurrently. The idea is that the concurrent nature of these processes significantly increases productivity and product quality. This way, errors and redesigns can be discovered early in the design process when the project is still flexible. By locating and fixing these issues early, the design team can avoid what often become costly errors as the project moves to more complicated computational models and eventually into the actual manufacturing of hardware.
As mentioned above, part of the design process is to ensure that the entire product's life cycle is taken into consideration. This includes establishing user requirements, propagating early conceptual designs, running computational models, creating physical prototypes and eventually manufacturing the product. Included in the process is taking in to full account funding, work force capability and time. A study in 2006 claimed that a correct implementation of the concurrent design process can save a significant amount of money, and that organizations have been moving to concurrent design for this reason.
Concurrent engineering replaces the more traditional sequential design flow, or 'Waterfall Model'. In concurrent engineering, an iterative or integrated development method is used instead. The difference between these two methods is that the 'Waterfall' method moves in a linear fashion by starting with user requirements and sequentially moving forward to design, implementation and additional steps until you have a finished product. In this design system, a design team would not look backwards or forwards from the step it is on to fix possible problems. In the case that something does go wrong, the design usually must be scrapped or heavily altered. On the other hand, the iterative design process is more cyclic in that, all aspects of the life cycle of the product are taken into account, allowing for more evolutionary approach to design. The difference between the two design processes can be seen in figure 1. A significant part of the concurrent design method is that the individual engineer is given much more say in the overall design process due to the collaborative nature of

concurrent engineering. Giving the designer ownership is claimed to improve the productivity of the employee and quality of the product that is being produced, based on the assumption that people who are given a sense of gratification and ownership over their work tend to work harder and design a more robust product, as opposed to an employee who is assigned a task with little say in the general process.

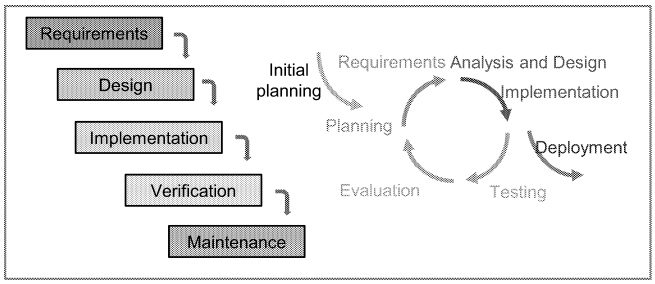


Figure 1: Traditional "Waterfall" or Sequential Development Method vs. Iterative Development Method in concurrent engineering

A significant part of the concurrent design method is that the individual engineer receives the chance to say much more in the overall design process due to the collaborative nature of concurrent engineering. The designer who receives from the leader the freedom to improve the productivity of the employee and the quality of the product stays in opposition with an employee that is assigned a task with little say in the general process. This remark is based on the assumption that people who are given a sense of gratification and ownership over their work tend to work harder and design a more robust product.

MECHATRONICS - A POWERFUL CONCURRENT ENGINEERING FRAMEWORK

Mechatronics is emerging as a concurrent engineering thinking framework in the process of designing complex machines. In a mechatronic system, the mechanical, electrical, and thermal components of a product are not only tightly integrated, but also connected through sensors and actuators with controllers that define the overall functionality. The performance engineering of such mechatronic products mandates simulation and test solutions that are capable of analyzing and optimizing the product performance. It is taking into account the interactions of components and subsystems in the product, each with their different physics representations (mechanical, thermal, fluids).

Both control system development and mechanical system development adopt the so-called "V - approach", propagating system level requirements to component design and validating the system performance at increasing integration levels. As figure 2 illustrates, the engineering of mechatronic systems requires the application of two interconnected "V-cycles": one focusing on the multi-physics system engineering (like the mechanical and electrical components of an electrical driveline); and one focused on the controls engineering, the control logic, the software and realization of the control hardware and embedded software.

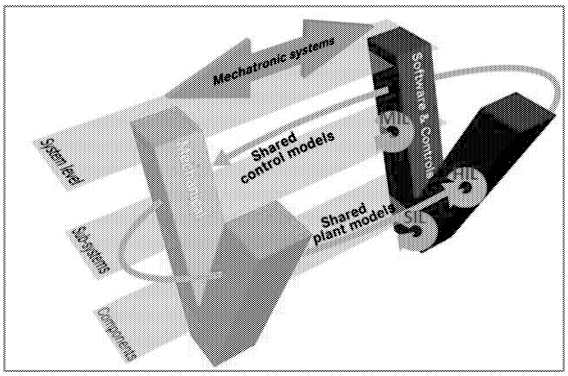


Figure 2: Double-V process for mechatronic systems

This approach includes the use of multiple models of different abstraction: requirement models, 0D and 1D functional and physics models down to 3D detailed design models. The term 3D refers to the association of the model with a geometry. In a 1D model, this connection is lost and components or subsystems are represented by icons connected to mathematical equations. 0D models describe systems with simple or tabular relations.

To engineer intelligent systems, an expanded need exists for multi-physics system modelling, simulation and validation. For example, a drive system requires models for the engine, driveline and brake system, covering kinematics, dynamics, structural analysis, hydraulics and including specialized bearing models.

Multi-physics system modelling, simulation and validation also needs to handle an increasing diversity and complexity of sensors and actuators used in mechatronic systems and to take into account the system's operating environment.

Integrating such models of different nature is a challenge. Interoperability requires common frameworks for variables and functions and well described interfaces. Major challenges towards achieving a realistic system-level performance prediction using heterogeneous models are (1) to link the world of 1D system and functional simulation with this of 3D geometry-based simulation (e.g. multibody or FEA/BEM models) and (2) to link time (e.g. time integration based) and frequency domain (e.g. eigenvalue solver based) simulation methods. Key enabling technologies hereto such as co-simulation and model reduction are intensively researched.

It is important to stress that mechanical and electrical-electronic system models must be integrated as soon as possible in the design process, enabling to reduce or even eliminate the divide between the two V-cycles of Figure 2 and leading to an integrated, multifunctional system mock-up approach to build the mechatronic simulation model, figure 3.

Another major challenge is to integrate the system and the control models. It consists of combining the multi-physics model with the controller model to enable the design of the

control logic and the performance engineering of the intelligent system. This is referred to as "Model-in-the-Loop" (MIL). The simulation is "off-line", i.e. no requirement for Real-Time performance of the simulation exists.

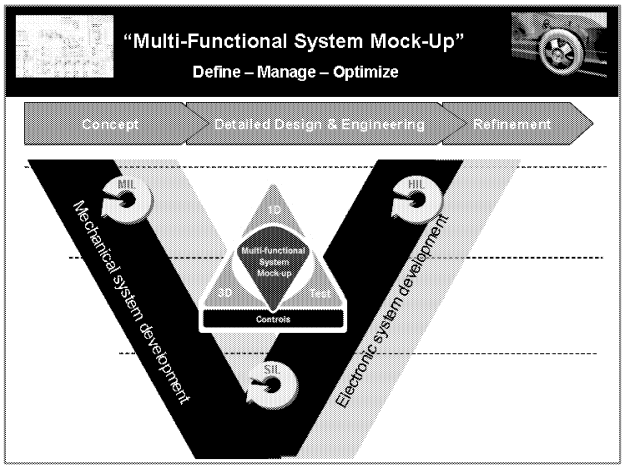


Figure 3: Integrated mechatronic simulation approach

Basically, two interconnected objectives can be distinguished. One is to perform systems engineering based on the multi-physics "plant" model, including the application (and hence representation of) control, for example for concept evaluation studies. The other is to perform control engineering, including a realistic model of the systems "plant".
This second objective is oriented to the development of the optimal control logic, the development and verification of control hardware, control libraries and embedded software up to the validation and calibration of the control system on the Electronic Control Unit or ECU, figure 4.

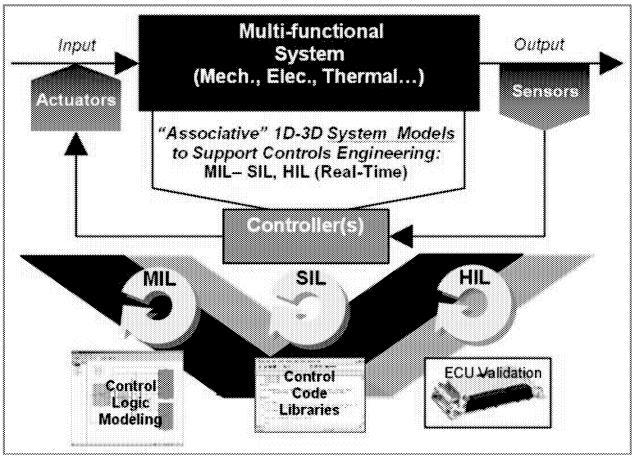


Figure 4: Associative 1D-3D models

The next step is the development and optimization of the "embedded" control software. This needs also to be done in context of the functioning of the multi-physics system to be controlled. This is referred to as "Software-in-the-Loop" (SIL).

The final testing and calibration of the controller software and hardware, requires the controller to be connected to a multi-physics simulation model of the components, subsystems or system, in a dedicated computing environment that is referred to as "Hardware-in-the-Loop" (HIL).

CONCURRENT ENGINEERIG PROBLEMS IN ARTICULATED VEHICLE STEERING SYSTEMS

An off-road vehicle is considered any type of vehicle, which is capable of driving on and off paved or gravel surface. It is generally characterized by having large tires with deep, open treads, a flexible suspension, or even caterpillar tracks. Other vehicles that do not travel public streets or highways are generally termed off-highway vehicles, including tractors, forklifts, cranes, backhoes, bulldozers.
To be able to drive off the pavement, off-road vehicles need several characteristics: they need to have a low ground pressure, so as not to sink into soft ground, they need ground clearance to not be hung up on obstacles, and they need to keep their wheels or tracks on the ground so as not to lose traction. Wheeled vehicles accomplish this by having a suitable balance of large or additional tires combined with tall and flexible suspension. Tracked vehicles accomplish this by having wide tracks and a flexible suspension on the road wheels.
The choice of wheels versus tracks is one of cost and suitability. A tracked drivetrain is more expensive and costly in terms of maintenance. Wheeled drivetrains are cheaper and give a higher top speed. Figure 5 shows an off-highway vehicle classification. Usual problems that manufacturers of these vehicles meet are presented in figure 6: transmission energy performance, stability problems, expensive physical powertrain testing, and simulation complexity too low, high power consumption, part break during operation, driver vibration comfort, and long and costly development cycle.

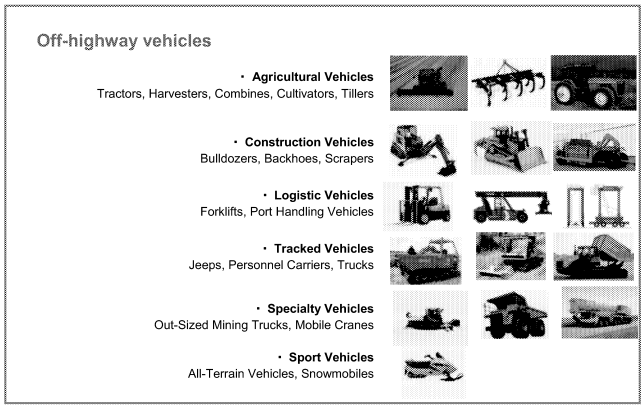


Figure 5: Off-highway vehicle classification

The introduction of articulated frame steering was a landmark in the development of off-road vehicles, especially for loading and earth-moving applications. This design significantly improved the level of maneuverability

and turning abilities of off-road vehicles, which led to a more efficient performance.

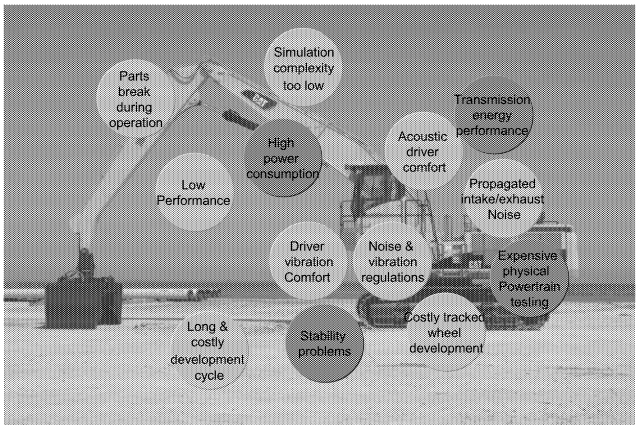


Figure 6: Overview about typical problems of the off-highway manufacturers (LMS document)

The typical steering layouts of off-road vehicles are the following: front or rear wheel steering, four wheel steering, twin axle steering and articulated frame steering, figure 7. For both technical and economic reasons, the articulated frame steering (Articulated Steer Vehicle – ASV) has become popular and an increasing number of manufacturers choose this simple but efficient steering system. Articulated frame steering is a type of powered steering system by which the relative yaw angle of two parts of the vehicle is changed, usually by two hydraulic actuators.

Mostly, ASVs have rigid suspension systems, and their flexible tires and a spring-mounted operator seat damp dynamic loads from the ground on the cab.

In an ASV, a torque converter may be placed between the engine and drive wheels to prevent the engine from going into a stall, although some ASVs have a direct drive design in which the engine is coupled directly to the transmission.

ASVs generally have a permanent four-wheel drive configuration. This drive configuration permits traveling on various surfaces, even muddy ground conditions.

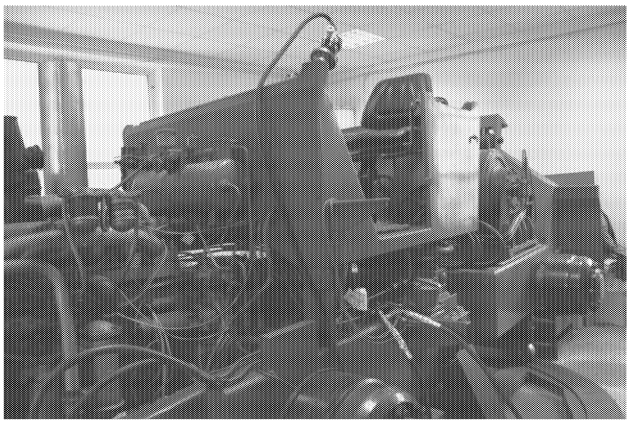


Figure 7: Articulated steer vehicle in the Fluid Power Laboratory of U.P.B.

The front and rear axles have transverse differential gears to transfer power to the left and right wheels that can be locked. A longitudinal differential may also be used between front and rear axles, which can be locked during travel on soft or icy surfaces by a differential lock. In some ASVs, the front and rear axles can be decoupled to transfer power to one of the axles.

Despite the above-mentioned advantages, the articulated frame steering layout introduces some problems to ASVs, including both roll and lateral instabilities in different situations.

In articulated vehicles, the front and rear sections affect one another due to the inner forces at the articulation joints. Therefore, the stability analysis of these vehicles is much more complex than that of single frame vehicles. Based on practical reports, both roll instability at low speeds and lateral instability at high speeds can occur for ASVs.

Roll instability is related to the possibility that the vehicle will roll over. Lateral stability requires that the vehicle remain in a state of equilibrium when it is subjected to a small disturbance, such as small movements of the steering wheel by the operator. The disturbing factor causes a perturbation of the vehicle lateral or yaw motion, and as a result, the vehicle may become unstable.

One of the main disadvantages of ASVs is the lateral instability while driving straight at higher speeds (Azad 2005). During travel on roads at high speeds, two types of lateral instability are possible: a diverging mode in which the front section of the vehicle tends to fold around the rear section, and a weaving mode in which the two sections of the vehicle oscillate, relative to each other at a frequency of approximately 1 Hz. These two modes are similar to the classic jackknifing and snaking instabilities of wheel steer articulated vehicles, such as tractor-semitrailers and car-caravan combinations. During on-highway travel in a straight line at higher speeds, the two segments of the vehicle oscillate with different phases relative to each other. The problems are assessed qualitatively only by drivers as weaving, wandering or snaking.

A NEW STEERING SERVOVALVE FOR ARTICULATED WHEEL LOADERS

A loader is a type of tractor, usually wheeled, sometimes on tracks, that has a front-mounted square wide bucket connected to the end of two booms (arms) to scoop up loose material from the ground, such as dirt, sand or gravel, and move it from one place to another without pushing the material across the ground. A loader is commonly used to move a stockpiled material from ground level and deposit it into an awaiting dump truck or into an open trench excavation.

An articulated wheel loader generates a shock at the starting stage of the steering operation. This shock deteriorates the driver's comfortless. A cushion valve (figure 8) was introduced to relieve it (Yong-Lak Cho and Dal-Sik Jang 2006). At the starting stage of the steering operation, the pressure of one cylinder rises suddenly. If

the pressure difference between two cylinders is over the setting value of the relief valve, oil flows from one cylinder to the other one though the flow passage which is controlled by the spool. The shock at the starting stage of steering and residual oscillations can be observed in pump pressure profile and mainly in the acceleration of body. The damping orifice diameter of the cushion valve can be tuned for limiting the undesired body oscillations.

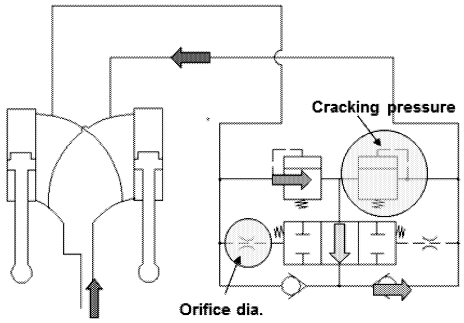


Figure 8: Steering system with cushion valve (Doosan, 2006)

The dynamic behavior of an articulated wheel loader can be easily studied in the early design phase of an ASV by numerical simulation with LMS-AMESIM code, which offers the entire set of needed components (figure 9).

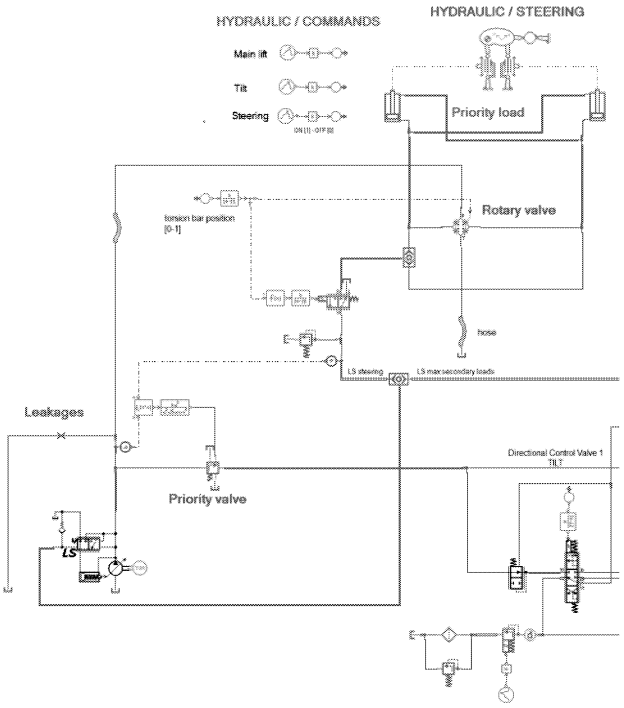


Figure 9: Steering system LMS-AMESIM model of an ASV with a load sensing pump

Some common simulation conditions for the steering units operation are the following: steering wheel speed: 50…60 rev/min; load pressure: 50…100 bar; steering system relief valves pressure: 120 bar. During steering system analysis, the dominant tuning parameters are tire stiffness, tire-road longitudinal friction coefficient, and Young's modulus of the inevitably hoses.

The numerical simulations performed for typical input signals, sited in the domain (-40°…+40°) show the great pressure surges generated by two opposite consecutive great inputs signals (figures 10, 11 and 12). A full overall rotation applied to the steering wheels in one direction generates small angular oscillations of the back frame, but it is not a common case. Steering pump pressure spikes for a loaded bucket depend on many parameters. One of the most important one is the tires lateral damping coefficient.

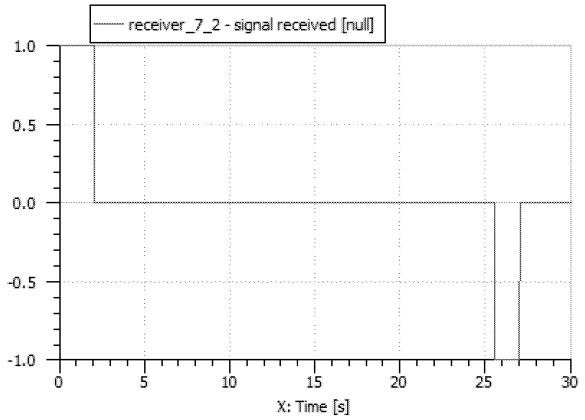


Figure 10: Typical full input for an ASV steering wheel

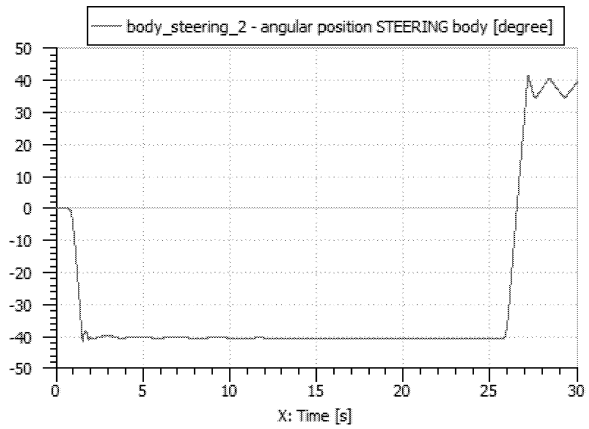


Figure 11: Angular position response of an ASV steering system for a typical input signal

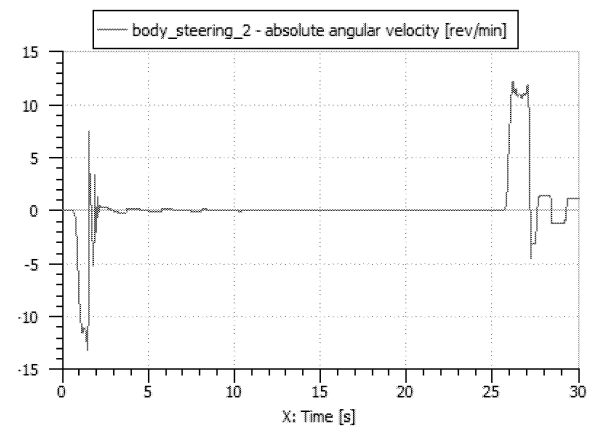


Figure 12: Absolute angular velocity response of an ASV steering system for a typical input signal

The high load ASV need a big flow steering system that includes a standard steering unit, and a flow amplifier with a variable gain. A medium swash plate axial piston servo pumps with pressure compensator supply the system. This configuration is a complex and expensive one, and not remote controllable. The combination between EHPS type 1, OSPCX CN steering unit and PVRES joystick produced by Sauer - Danfoss Corporation solves completely the problem of manual and remote steering control. The vehicle can be steered with either the PVRES joystick or the OSPCX CN steering unit. The signal from the steering unit has priority on simultaneous activation of steering wheel and joystick.

The authors of this paper studied the possibility of replacing the full mechanical steering system for different type of ASV by an electrohydraulic one exclusively, including an electrically operated steering valve, with the same basic function as EHPS type 1, but with an original design.

Taking into account the peculiarities of the new generation of remote controlled ASV, both single stage direct drive industrial proportional servo valves, and two stages ones were simulated and tested using a full hydrostatical forestry tractor (Irimia et al. 2013) running in the Fluid Power Laboratory from the University POLITEHNICA of Bucharest. The need of a nonlinear behavior for any steering valve leaded the authors to a special design based on shaped metering windows (Calinoiu et al. 2013). The AMESIM simulation network for the electrohydraulic servomechanism with nonlinear two-stage servovalve is presented in figure 13.

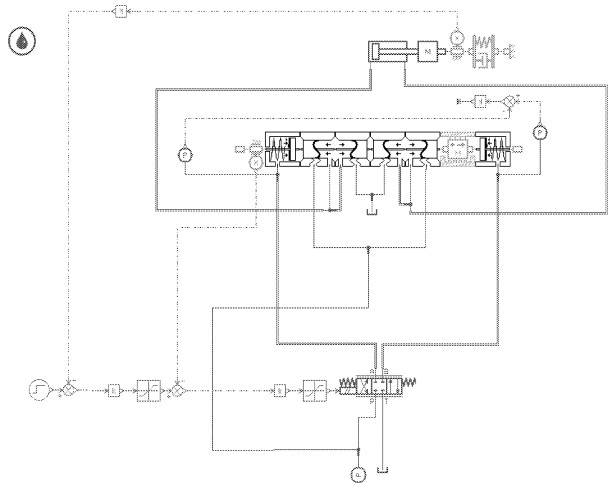


Figure 13: AMESIM simulation network for a high flow electrohydraulic steering servomechanism

The simulated input step response of the above system (figure 14) shows a good response time and the lack of the oscillations. The two slopes of the steady-state characteristics of the servovalve power stage solve both important steering problems: precision and control stability. This original servovalve design is now being patented in Romania. To validate the simulation model, the experimental results were compared with the numerical ones. The comparison was done for two cases: slow and fast steering, and for both types of servovalves: single stage and double stage. A view of the location of the position transducer set up on the back frame is shown in figure 15. The reference needed for the performance validation comparison was, obtained by driving the steering shaft of the hydro mechanical steering valve with a hydraulic motor, using a local angle feedback (figure 16).

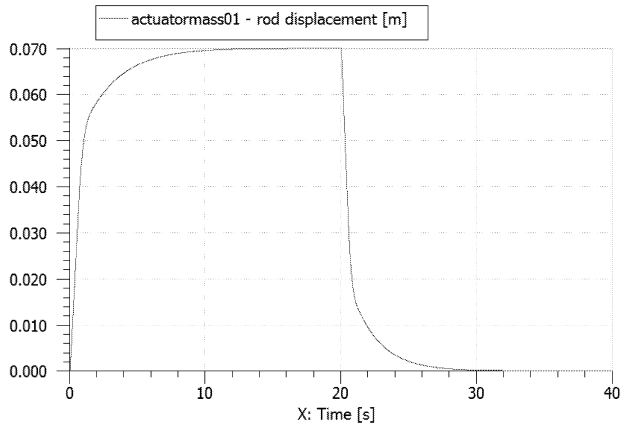


Figure 14: Step input response of the a high power electrohydraulic steering servomechanism (simulation)

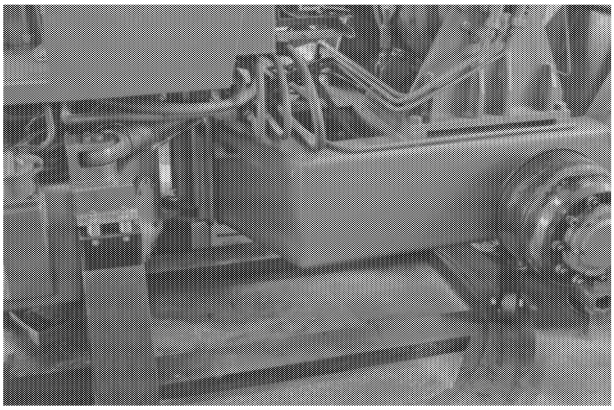


Figure 15: Hydrostatic tractor back semi-truck with small contact pressure guiding rollers (no lateral damping)



Figure 16: Hydro mechanical steering valve driven by an

ORBIT motor included in an electrohydraulic rotary loop The small speed linear inputs are well followed by the whole hybrid rotary positioning system (figure 17).

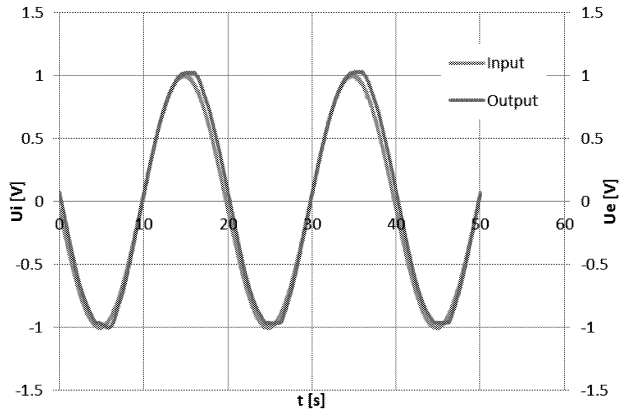


Figure 17: Hybrid steering system response for low frequency sine input signal

The steady-state characteristics hysteresis (figure 18) is small enough for an open center steering valve, controlled by such a long electrohydraulic and mechanical "chain".

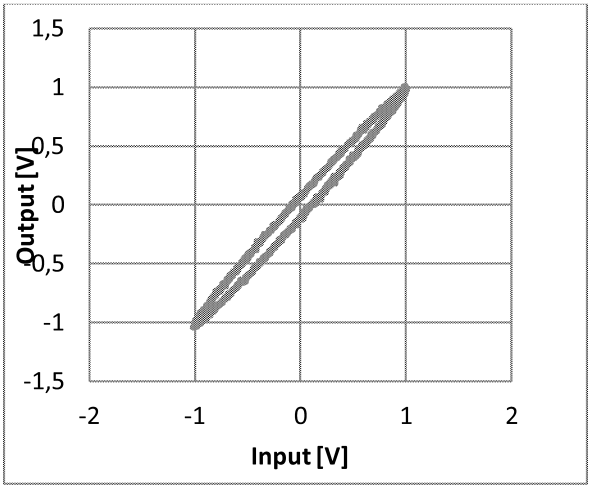


Figure 18: Hybrid steering system steady state characteristics for low frequency sine input signal

All the experimental results are found in good agreement with the practical AVS needs (Irimia et al. 2014). However, the lateral tire damping assessment and other AVS peculiarities can oblige the designer to change the tuning parameters of the controllers (Azad et al. 2005; Horton et al. 1986; Martyna 1988).

CONCLUSIONS

The concurrent engineering design cycle includes simulation and test procedures that are capable to predict, analyze and optimize the performance of multi-physics and mechatronics products. Any designer needs to take into account the interaction of different subsystems with sensors, actuators and controllers (Van der Auweraer 2009). The main objective of any engineer is to offer a high-speed optimal design. This target needs tools and interfaces which accelerate and optimize the design. From this point of view, it is obvious that AMESim (LMS INTERNATIONAL 2012) is a complete software perfectly adapted for model generation and implementation in different domains, not only mechatronics. For example, a modern trend in the agriculture is about making farming processes more accurate, efficient, and sustainable through the use of advanced satellite navigation systems (like GPS) and Information Technology (IT).

Precision Farming is raising the agriculture to a new level: doing the right thing, in the right place, the right way, at the right time in the field. Apart from satellite navigation systems, Precision Farming makes use of a number of other key technologies (ATB 2010).

They include automated steering systems, which take over specific driving tasks like auto - steering, overhead turning, following field edges and overlapping of rows. On tractors, combine harvesters, maize harvesters and other simulate vehicles there is often a need for electrically actuated steering to make automatic GPS controlled steering possible. In addition, manual steering with variable ratio is an often-wanted feature to improve productivity and driver comfort. For this purpose, some important companies have developed combined steering unit and electro hydraulic steering valves. The new high power steering system proposed by the authors can contribute to this important domain. The future seems to be directed towards digital input servovalves (Voss, 2005; Ganziuc 2013; Köhler 2011; Meek et al. 2013).

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A NEW TYPE OF ELECTROHYDRAULIC VALVETRAIN SYSTEM

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KEYWORDS

EHVS, Diesel engines, modeling, simulation, experimental tuning, concurrent engineering

ABSTRACT

The paper presents modeling, simulation, design and experimental identification of a new electrohydraulic valvetrain drive system (EHVS) for internal combustion engines patented by some of the authors. Both hydraulic scheme and design features are presented, in close connection with the peculiarities of the classical Diesel engines for locomotives. The experimental investigations were carried out in the Fluid Power Laboratory of the University POLITEHNICA of Bucharest, using original components manufactured by HIDRAULICA BRASOV Company, combined with high performance electrohydraulic industrial servovalves, and high-speed real time digital controller. The actual system performances are found in good agreement with the requirements of the high power modern Diesel engines. The practical conclusions of the research are very useful in a concurrent engineering approach of any heavy automotive application.

EHVS FEATURES

For over a century, the internal combustion engine has been the motor of the industry and of man's everyday life. Since the first models, a constant evolution is bringing the engines closer to perfection. This progress is mainly the result of global environmental concerns about increasing pollution with gases and decreasing fossil fuel resources. The main disadvantage of the classical engine design was the use of the traditional camshaft in the actuation system. In order to create even more economical and cleaner engines, new solutions of performance improvements are required. A new approach is the use of an electrohydraulic valvetrain system in order to eliminate the camshaft and create a reliable and fully flexible valve actuation system (Bosch 2004; Sturman Industries 2005; LMS). The engines requirements for a flexible valvetrain drive system led the engineers to various designs of electrohydraulic, electromechanical and electropneumatical systems used by several engine manufacturers. Unlike conventional camshaft driven systems and cam-based variable valve timing techniques, a pure electrohydraulic system offers full management on the valve timing and lift control, fully independent of crankshaft position and engine speed.
Some practical implementation of the EHVS developed by Sturman Industries in 2008 for General Motors have shown the following benefits of camless engines, confirmed during official assessment: independent valve lift and timing control allowing for a mixed-charge combustion and low parasitic loss, since most of the conventional valvetrain (including the camshaft) is eliminated; high-speed engine operation (up to 12,000 rpm); enable homogeneous charge compression ignition (HCCI) combustion; enables cylinder de-activation and cylinder balancing; scalable to any engine size, and can be retrofitted to older engines since all the technology is in the head; compatible with any fuel type; a square lift pattern compared to the lobe profiles a camshaft requires; can be used to create an internal EGR system; potential up to 60 percent thermal efficiency; can be used to help eliminate the need for an exhaust after treatment.
Although flexibility of a camless valvetrain is limitless, their construction is more complex, more expensive and require deeper studies.
On the other hand, the cam-based systems are well documented, are more reliable and robust but, the do not offer the required flexibility in operation (Grünwald 1988).

EHVS TYPES AND PERFORMANCES

One method of adjusting valve timing and lift, given a fixed cam profile, has been to incorporate a "*lost motion*" device in the valve train linkage between the valve and the cam (Vorih and Egan 2001).
Lost motion is the term applied to a class of technical solutions for modifying the valve motion proscribed by a cam profile with a variable length mechanical, hydraulic or other linkage means. In a lost motion system, a cam lobe may provide the "maximum" (longest dwell and greatest lift) motion needed over a full range of engine operating conditions.
A variable length system (figure 1) may then be included in the valve train linkage, intermediate of the valve to be open and the cam providing the maximum motion, to subtract or lose part or all of the motion imparted by the cam to the valve.
This variable length system (or lost motion system) may, when expanded fully, transmits all of the cam motion to the valve, and when contracted fully, transmit none or a minimum amount of the cam motion to the valve.

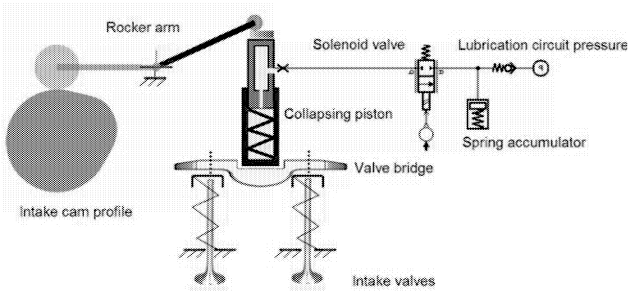


Figure 1: Electro-hydraulic Lost-Motion System for valve actuation (LMS AMESIM model for VVA)

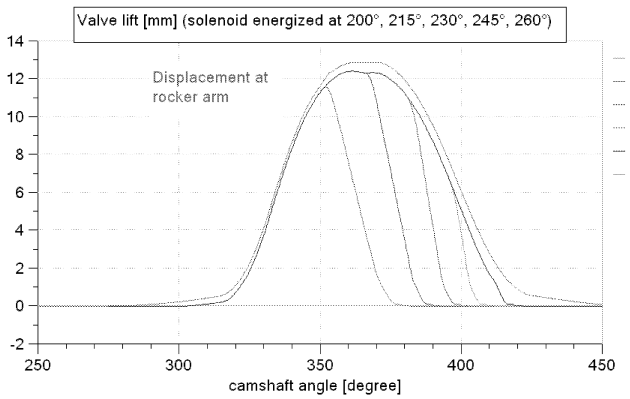


Figure 2: Valve lift versus cam shaft angle for different angles of solenoid activation (simulations with LMS AMESIM model for VVA)

An electrohydraulic valvetrain system with two solenoid valves with two-ways was developed by Robert Bosch GmbH in 2004 (figure 3).

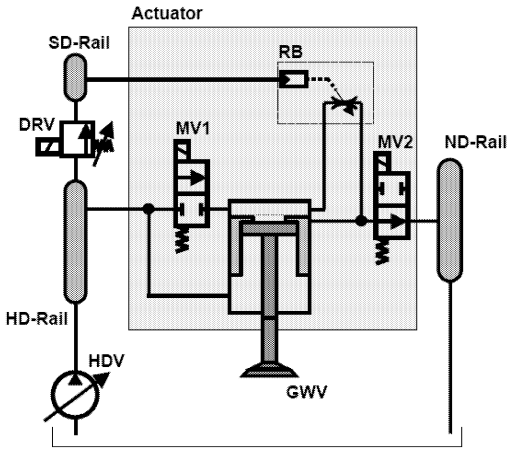


Figure 3: BOSCH EHVS with 2 two-ways solenoid valves

The EHVS developed by BOSCH for internal combustion engines eliminates the valve closing spring. It has the following major advantages:
a) in the matter of *Fuel consumption/Efficiency*: minimization of gas exchange losses (*dethrottling*, with manifold injection); valve cutoff, cylinder cutoff, multi-stroke operation; reduce of idle speed (more stable due to less residual gas);
b) in the matter of *Torque curve/Power*: operating-point-dependent optimization of valve timing and stroke exhaust gas; operating-point-dependent variation of the charge motion; variable internal exhaust gas recirculation (EGR); less assembly groups; reduced size of the engine; more efficient engine brake; new starting strategies; more efficient engine brake; new starting strategies.
The simultaneous and uncoupled optimization of the fuel consumption and the emissions requires the independent control of fresh mixture, residual gas and charge motion. For this, the opening and closing angle and the stroke of the individual gas exchange valves are to be controlled cycle to cycle conform. The system‘s fail safety, especially the fail safe position „gas exchange valve closed“, is to be considered in the system‘s design.
In order to achieve a low-cost serial production with a high number of pieces there is to be aimed a use of the control principle as well as the partial components with all known engine types and combustion concepts. All material, partial components and production processes necessary for the system‘s assembly are to be selected in compliance with the criterions availability and process safety. The different engine types which are all to be covered with the same principle require a broadly applicable range relating to the parameters „force“, „stroke“ and „valve velocity“. Operational parameter‘s combination is very wide: high force (>1000N), velocity (10mm/2,5ms), stroke (>10mm); valve velocity and braking behavior adapted to operating point; valve free travel is not always to be assumed; cylinder head with actuators have to be checkable as module. Afterwards installation of the whole module on the engine block is possible the exchange of individual actuators installed on the mounted cylinder head at temperatures between -40°C ... 140°C.
The repeatability of the valve stroke of this system is remarkable (figure 4).

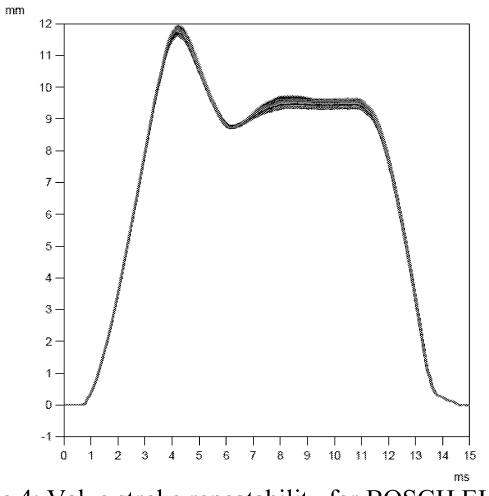


Figure 4: Valve stroke repeatability for BOSCH EHVS: 50 strokes obtained for the same valve with a constant supply pressure of 250 bar

Another practical implementation of the EHVS was developed by (Sturman Industries 2008) for General Motors, and International DT466 6.0L Power Stroke.

The Sturman's Camless Engines uses a new type of three ways high-speed directional valves with a high timing accuracy, specially developed for this type of drive.

NEW DESIGN DESCRIPTION

The new design was implemented on a standard cylinder head of a 1.200 HP Diesel engine from a Sulzer 12LDA28 locomotive (figure 5). Two camshafts actuated the four valves against twin helical springs.

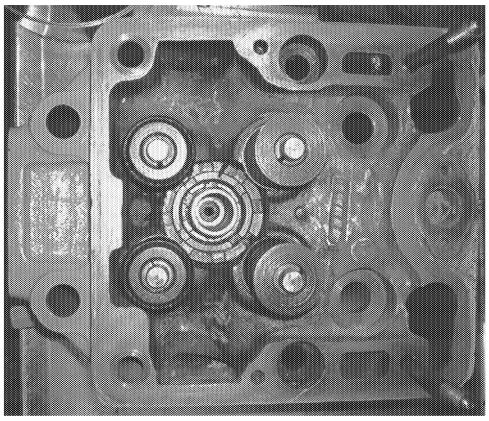


Figure 5: Head of a cylinder used in a Diesel engine from Sulzer 12LDA28 locomotive

The main idea of the new design, presented in the figures 6…10, is the use of a four way, high-speed, industrial servovalve D1FP produced by Parker Corporation. The first prototype used a plunger for valve opening. The two original springs were used for closing the valve. This simple design was not useful because the resonance between the hydraulic cylinder, and the springs was strong and unpredictable. The final design eliminates the springs and use a symmetric hydraulic cylinder for driving each valve in both directions. The optimal control of the valve position needs a feedback supplied by a special type of eddy current position transducer (VRVT) connected with the piston rod. The valve motion is controlled by a PT1 servo controller connected to a NI DAQ board. The LabVIEW software is used for generating a composed input signal. The numerical simulation performed by Simulink and AMESIM languages (figure 11) have shown that a simple rectangular input signal cannot be used for obtaining high frequency valve motion. A composed input signal (figure 13) using both positive and negative voltage can generate the proper valve opening for different frequencies from the needed speed range of the engine. Figure 14 shows different valve lift curves generated with composed signals.
The servovalve was supplied by axial pistons swash plate variable displacement pump from series PV46 (Parker) delivering 45 l/min for 250 bar. Two bladder accumulators wer used for avoiding strong pressure surges in the hydraulic lines. The drive of two valves with the same servovalve needs both higher flows, and a high-speed flow divider.

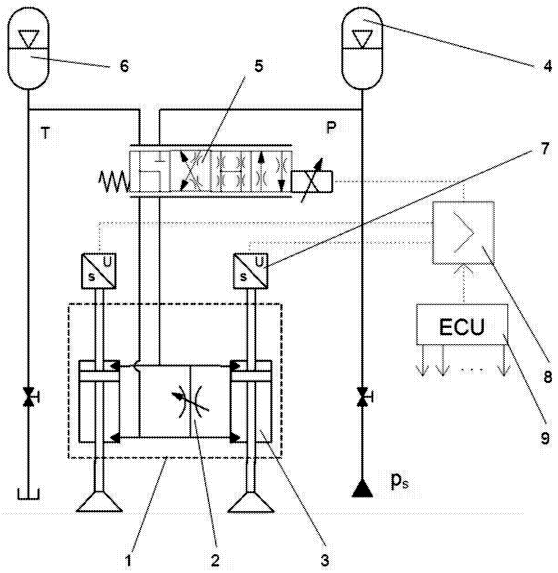
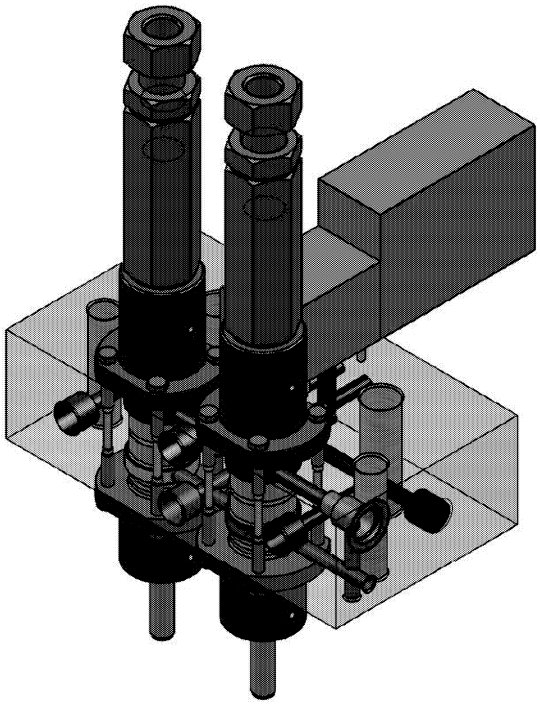


Figure 6. Hydraulic scheme of the new EHVS



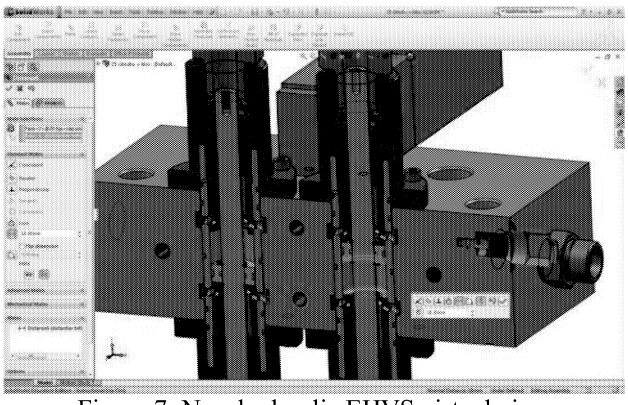


Figure 7: New hydraulic EHVS virtual view (SolidWorks model)

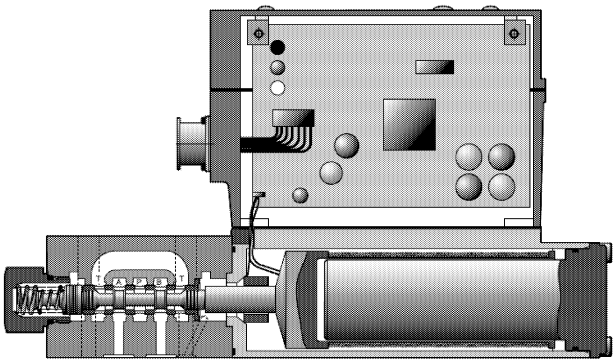


Figure 8: D1FP Parker high-speed industrial servovalve

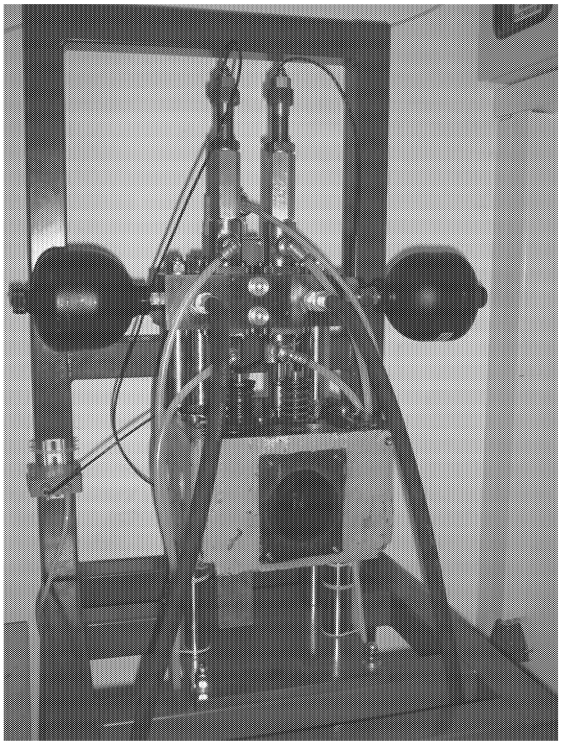


Figure 9: Partial view of the EHVS test bench

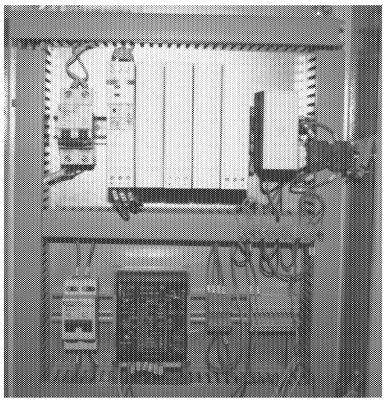


Figure 10: Test bench control panel partial view

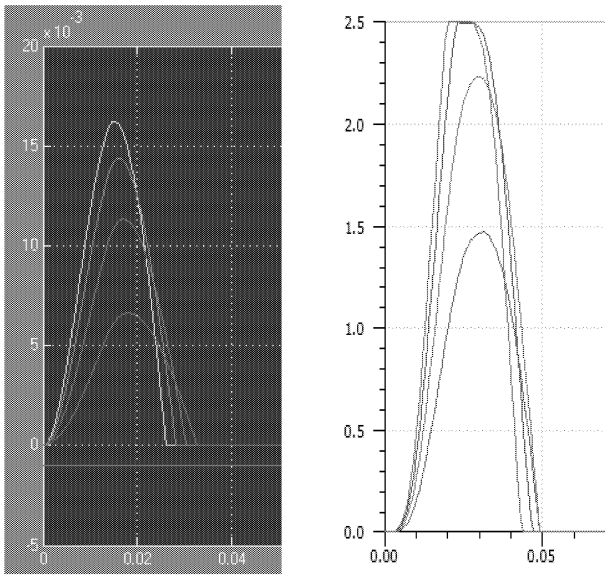


Figure 11: Simulated openings of the valve for different rectangular input signals by Simulink and AMESIM

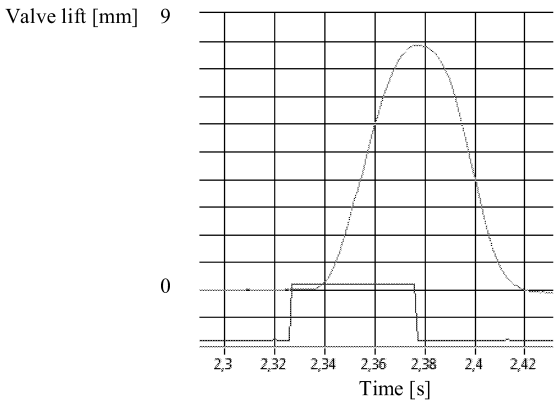
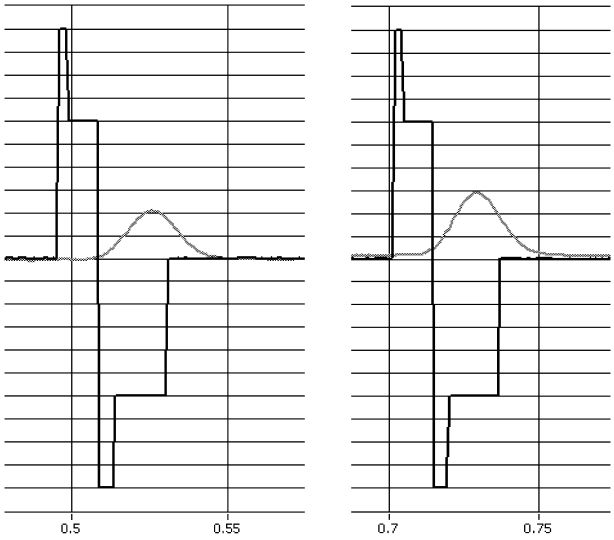


Figure 12. Experimental valve lift for a rectangular input signal (U=1V and P_S=100 bar)



P_S=150 bar P_S=200 bar

Figure 13: Optimal composed input signal and the valve lift for f=6,25 Hz and different pressure supply values

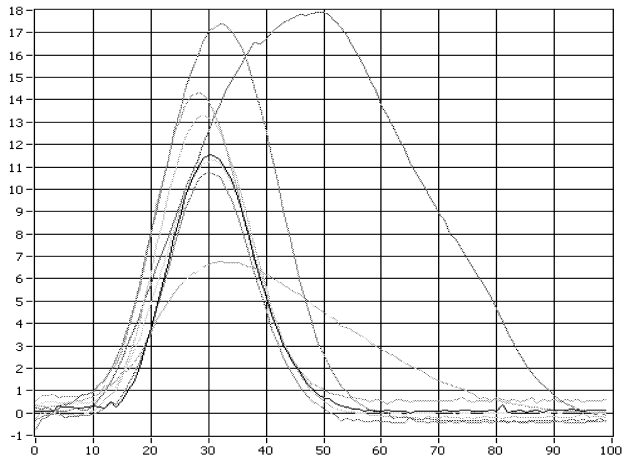


Figure 14: Different valve lift curves generated with composed signals

CONCLUSIONS

The preliminary researches have shown a real potential for the new design to accomplish all the conditions needed to control a Diesel engine. However, a big amount of researches is still needed for implementing this new idea on a real engine. At the same time, the high performances obtained by the development of other electrohydraulic automotive applications are encouraging the authors to refine the results by both numerical simulations and practical implementation of the new solution. The whole activity revealed the great utility of the numerical simulation in the frame of a concurrent engineering approach.

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USING LABVIEW FOR DESIGN AND DEPLOYMENT OF ADVANCED DIGITAL PROTECTIVE RELAYS

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KEYWORDS

Modeling and simulation, Design, Prototype, Deploy, Digital Protective Relays

ABSTRACT

In the presented paper we will present the design and deployment principle for a Digital Protective Relay (DPR) using the V-Diagram approach. We will have an overview of the current technologies available for DPRs and present a software-defined approach for a complete tool chain in Design, Prototype and Deploy using Graphical System Environments and Off-the-shelf Hardware platform.

INTRODUCTION

The evolution in technology including communications developments, information systems and software tools for advanced prototyping are opening a new era for Digital information. All around us, the information is digitized and stored allowing new sets of equipment and applications to be developed as an answer to Smart Grid requirements. A smart grid solution requires integration of multiple intelligent electronic devices (IED), usually from different vendors with open or closed functionality and with standard communication protocols. Nevertheless, integration of multiple IEDs in a supervisory control and data acquisition (SCADA) system is a complex process and entails vendor-defined limitations. The ability to simulating and controlling the functionality of each IED type under various power system events, recorded from real life or simulated, allows the design and development of new smart grid applications.
Digital Protective Relays (DPR) recorded a high increase in presence in the last decade throughout the power systems. They are the answer for smart grids with high volumes of data when events are occurring in the line. The ability to monitor and record data from voltage and current waveforms , the status of the digital contacts (Costello 2000), the capacity of onboard real time processing provide a new functionality opposed to traditional electro-mechanical or solid state relays which has simple protective roles.
Large-scale deployments of DPRs require the ability to synchronize them through GPS in order to have a real time capability of preventing blackouts in the system. Relay wrong operation is the main cause in cascading events, which lead to blackouts. Usually system operators will take a false decision because of the little information obtained from traditional digital relays. The current paper is proposing an open way of integrating different algorithms, models or functionality using a graphical system design approach in order to be able to design and build smarter and more complex DPRs. We will analyze the status of the DPRs, the most common functionality, the way we can integrate all of this information from different sources and automate a test bench for simulation and testing.

BACKGROUND

In the electrical engineering field, a *protective relay* is a device designed to trip a circuit breakers when a fault is detected. The first protective relays were electromagnetic devices, relying on coils operating on moving parts to provide detection of abnormal operating conditions. Protection relays respond to such conditions as over-current, over-voltage, reverse power flow, over- and under- frequency. Distance relays trip for faults up to a certain distance away from a substation but not beyond that point. An important transmission line or generator unit will have cubicles dedicated to protection, with many individual electromechanical devices, or one or two microprocessor relays.
Microprocessor-based digital protection relays now emulate the original devices, as well as providing types of protection and supervision impractical with electromechanical relays. In many cases, a single microprocessor relay provides functions that would take two or more electromechanical devices. By combining several functions in one case, numerical relays also save capital cost and maintenance cost over electromechanical relays.
However, due to their very long life span, tens of thousands of these "silent sentinels" are still protecting transmission lines and electrical apparatus all over the world. The theory and application of these protective devices is an important part of the education of an electrical engineering that specializes in power systems. The need to act quickly to protect circuits and equipment as well as the public often requires protective relays to respond and trip a breaker within a few thousandths of a second. In these cases, it is critical that the protective relays are properly maintain and regularly tested. The rapid development and testing can have a more dynamic

approach, based on the high-developed tools and principle: Software in the Loop (SIL), Model in the Loop (MIL), Processor in the Loop (PIL) and Hardware in the Loop (HIL). These four stages allow a more rapid prototyping and development, a better identification of algorithm failure and a perfect environment for testing and error simulating to prevent blackouts in the power systems.

MIL - We are using a model of the control to work with a model of the plant. The control mathematical model is connected directly to a physical model of the system within the same simulation environment. Extremely fast development occurs at this stage as you can make small changes to the control model and immediately test the system.

SIL - The control model is slightly more "real" in the sense that you no longer need to execute it but rather you have probably coded the model into C or C++ and then inserted this coded model back into your overall plan simulation. This is essentially a test of your coding system (whether auto coded or human coded). Design iteration slows down slightly from MIL but coding failures start to become evident.

PIL - This is a case where you no longer run your coded system in simulation but rather deploy it to a representative microprocessor. While the code is running on the microprocessor, the IO to the plant model is probably connected to your plant simulation via a high-speed bus. This test is designed to expose problems with execution in the embedded environment. For instance, does your control loop fit within the execution time available on the embedded processor. Design iteration slows noticeably at this point as you must both code and deploy changes to your control system. However, exposing execution issues on the embedded processor are easy to find and fix at this stage.

HIL - This is a case where your control system is fully installed into the final control system and can only interact with the plant through the proper IO of the controller. The plant is running on a real-time computer with IO simulations to fool the controller into believing that it is installed on the real plant. In this case, the only difference between the final application and the HIL environment is the fidelity of the plant model and the test vectors that you are using. HIL is often used only for software validation rather than development as the design iteration is very slow at this point. However, this test is closest to the final application and therefore exposes most of the problems that will be seen.

FAULT RECORDING, ANALYSIS, AND LOCATION DETECTION

Due to their record capabilities and fast acquisition rates DPRs can incorporate multiple functionalities. Depending on the hardware architecture of the DPR, the microprocessor used, how big the local memory and the processing capabilities are, a DPR can have beside the protective function, fault recording, fault analysis, fault location, phases measurement unit (PMU) or even power quality analyzer (PQA). Each one of them should be seen as a specific set of functions (dll), that is applied to the raw data of voltage and current waveforms. A fast remote terminal unit (RTU) will have the on-line processing capabilities for all of them. Bellow we will explain the functionality for some of the most common ones

Fault recording

Modern digital relays are capable of generating various files and reports, each of which may address a specific purpose. Generally, an oscillograph file records what a relay "sees" during disturbance events. A setting file specifies how the relay is configured.

A fault report presents parameters calculated by the relay for its decision-making. An event report reveals how the relay actually responds to the disturbance events according to its decision. These functions (fig.1) usually are input and output contacts, protection elements, control elements and pilot schemes (Luo 2005).

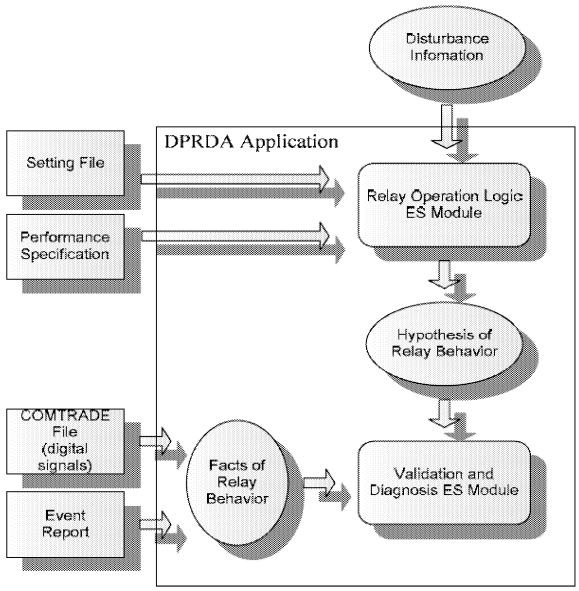


Figure 1: Functional Modules for DPRs

Currently a set of algorithms that can perform fault analysis. The basic ones are based on DPR settings. Usually this approach is a tradeoff between accuracy and speed as well as dependability and security. If settings are not done properly, it may result in less accurate decisions causing relay miss operation on certain occasions (Zhang 2003).

More advanced techniques are involving a Neural Network (NN) approach capable of providing the decision about the fault existence and fault type as discrete outputs. By using this NN solution, the performance of the function is improving while the implementation is indeed straightforward.

Most interestingly, this technique does not use the traditional settings and hence is not vulnerable to the inaccuracies in the settings. After a trigger, the event is recorded for future analysis. Usually an event contains pre-Fault data and post-Fault data (see Figure 2).

Figure 3 shows how an event recording looks like. An important factor is the use of COMTRADE files for transparent reporting and communication between multiple DPRs from different vendors.

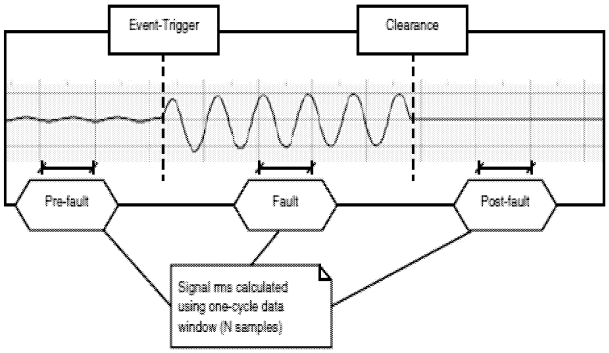


Figure 2: Event triggered fault recording

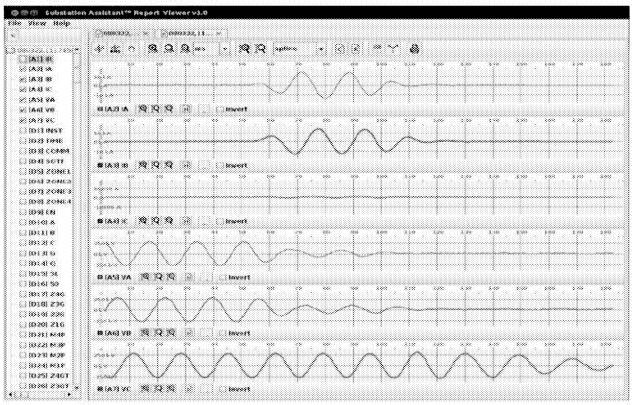


Figure 3: Event recording visualization

FAULT DETECTION AND ANALYSIS

Synchronized sampling based Fault locations (SSFL) are used to determine accurately the location of the fault in a transmission line. Synchronized sampling based fault location algorithm uses raw samples of voltage and current data synchronously taken from the ends of the transmission line. This can be achieved using Global Positioning Satellite (GPS) receivers, which generate the time reference for data acquisition equipment. Such an algorithm requires less than a cycle of the voltage and current data and can be used for real-time monitoring and protection applications (Kezunovic 1996). The main advantage of synchronized sampling based fault location algorithm is the simple implementation that only requires the line model and control of the samples at the two ends of a transmission line. The algorithm does not depend on any assumptions about system operating conditions, fault resistance, fault waveforms, etc. (Popovic 2013)
Newer and more accurate algorithms used a combination of the NN and SSFL. While the first one is working on-line, the second can perform calculation to confirm the existence of the fault. Both of them have as inputs the same raw data, voltage and current waveform from the 3 phase systems. The SSFL algorithm accuracy can be improved by providing as an input the classification of the fault type made by the NN (Popovic 2013).
A set of newly developed modeling and simulation tools aimed at better understanding the design concept and related applications for protective relaying, as well as substation communication and automation solutions are presented. These tools include a set of software, named MERIT 2000 developed using LabVIEW control design and Simulation module, AMESim or MATLAB/ SIMULINK (Ren 2010). The ability to build models for DPR and model for the power line is opening new opportunities for simulation and testing the algorithms using the model in the loop (MIL) method. The usage of an open and flexible graphical system programming language like LabVIEW allows an easy integration of the Matlab/Simulink models for a system characterization. During this process the ability of simulating corner case conditions will create a more stable and precise DPR model that will be later on implemented on off the shelf hardware platforms. The ability to easily replace the power lines model with real recorded signals brings value to the model validation phase.

LabVIEW INTEGRATION OF THE ADVANCE FUNCTIONALITY

New principles of Graphical System Design can speed up the process of developing, testing and deploying algorithms and software modules using off the shelf hardware platforms for rapid prototyping of new generations of DPR.
The same principle is used in the automotive industry where the functionality and complexity of algorithms is continuously increasing while the time to market and cost requirements are shrinking. The basic concept of the V-Diagram can be seen in figure 4.
CompactRIO is an off the shelf RTU platform from national Instruments that natively integrates with LabVIEW. The switch from MIL which is done under windows OS does not require any changes in your application. The benefit of an off the shelf platform is the high level integration between IO, processor, memory and communication. Drivers give you an abstraction layer that allows focus on the models and algorithms functionality and performance.
Integrating extra functionality for data analyses like the functions described in chapter 3 can be done in several ways. You can import this set of functions as dll's or you can build them in LabVIEW using a vast pallet for time or frequency domain analysis. The integration between the DPR model and the data processing functions is performed under the Software in the loop phase. The integration under a Real Time OS will provide a realistic performance of the overall system when it comes to timing constrains or algorithm limitations. Adding extra functionality like PMU or PQA is easy to implement and it comes with no extra cost, as everything is Software oriented. After tuning the algorithms and assuring system stability in various

operating scenarios, we can move to HIL phase. HIL consists of using the same models and algorithms in the same RTU platform while connecting it to real signals. The best practice in this direction is connecting the DPR RTU prototype platform to an RTU simulator, through real signals, which will have the capability of simulating real time conditions; at this stage, we will generate not only voltage and current signals but also the rest of the digital contacts. Having a separate RTU simulator allows for automated testing of all the possible scenarios to minimize the software bugs and have a final validation of the prototype.

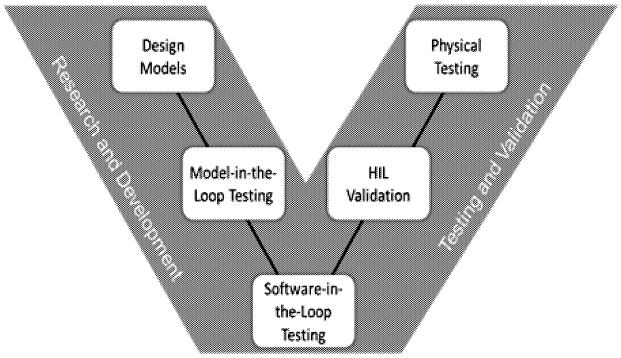


Figure 4: V-Diagram design process

The RTU simulator will integrate the power line model as well as the control to all digital contacts for error simulating. The capability of adding noise or simulating defects strengthens the algorithms and the model. Any bugs found in the process will determine a step back in the curve to MIL or SIL level depending on the gravity of the error. Working in the same programming environment allows easy returns in the process for modification.

FPGA allows parallelism in programming, which is essential in complex applications where we want to implement different functionalities on the same equipment. The FPGA circuit runs the algorithm with a clock of 40 MHz, which allows fast reaction time from the system. For example a trip circuit can be activated 1 cycle after the trigger which means a 25 ns delay in the processing.

After the HIL validation, there is a high probability that our prototype is functional and tested. The implementation of all the new data processing algorithms assured the stability of the system. The last phase of the project is the final deployment. CompactRIO platform can be used as a deployment platform, so all the code validation, IO integration, communication that is testing was done previously in the HIL phase.

We can connect the system directly into the power lines circuit for final testing. At this stage the only modifications that we can do to increase the time loop for the processing or to increase the reactions speed for the trip circuit is to move parts of the code from the RT processor to the on-board Field Programmable gate Array (FPGA) on board of the platform (see Figure 5). The same time implementing more code in the FPGA will offload the RT controller, so more functionality can be implemented.

The diversity of IO modules available in the CompactRIO platform allows direct connectivity to 3 phase systems, direct connectivity to digital lines as well as GPS synchronization with the rest of the systems in the network.

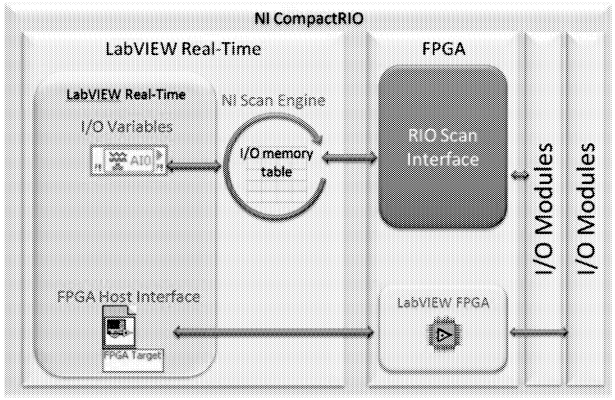


Figure 5: NI CompactRIO arhitecture

CONCLUSIONS

The use of an open graphical programming platform like LabVIEW™ allows integrations of models, code and algorithm from other programming languages. The SW abstractions layers allows focus of model and algorithm functionality, which it does not on low-level drivers programming. Using one SW platform for the whole cycle ease stepping back and forward in the V-diagram when errors occur. Off the shelf HW platform with RT OS and FPGA, with diverse IO connectivity allows faster prototyping and easy deployment. Having the possibility of passing algorithms from Windows OS to Real Time OS, and later on to FPGA target, without changes in the code is a huge advantage for the whole development cycle with big saving of cost and time. Open SW and HW platforms give the flexibility of adapting very easily, with minimal or no cost, to new functionality, new standards or custom requirements (Gheorghe 2013).

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USING VIRTUAL LABORATORIES IN CONCURRENT ENGINEERING

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Concurrent engineering, virtual laboratory, web data acquisition, test bench, flow servovalves.

ABSTRACT

The performance identification of the hydraulic control system requires complex equipment. The main practical component of an educational process is the student's direct contact with real hydraulic control systems. A modern way to solve this problem is to create a web interface between a modern laboratory and the students. This paper describes the first national virtual laboratory interface for testing hydraulic proportional flow valves, created by the authors in the frame of a RENAR certified laboratory.

INTRODUCTION

The study of fluid power systems behavior requires a great amount of laboratory time in order to understand the influence of each parameter on the systems performances. In a traditional educational laboratory, students have to identify the structure of the system they are testing, then to generate some inputs, and finally - to measure certain operational parameters using some instruments, usually analog ones. The discreet values obtained systematically are recorded in .xls files and turned into performance curves. This test manner is time consuming, and leaves little time for a deeper study of the input quantities influence on the system performances.
Modern laboratories are using data acquisition systems from sensors and transducers, controlled by industrial computers with real time control software. This new education manner needs a big amount of knowledge in other different fields than fluid the power one: SCADA systems, sensors, transducers, and digital control languages. These multiple tasks can be avoided by the aid of a friendly data acquisition interface with simple input entities, which reflects the test strategy only, and the data storage into common files for graphical presentation. This test manner allows the study of both static and dynamic behavior of the systems, and enables the student to stay focused on the main target of the laboratory only. Such an interface can be too small for really involving students in the core of the laboratory activity.
They allow a multi user approach where each student can perform the test individually, and then he can process the test results off line. The users can change various input parameters from any location by logging into the laboratory server, where they get a response in real time.
The Fluid Power Laboratory team from the Department of Hydraulics, Hydraulic Machines, and Environmental Engineering developed a full virtual laboratory devoted to the electrohydraulic proportional servovalves, included in the National IT Platform called "ITFPS" (Vasiliu D. and Vasiliu N. 2013). This new academic facility was developed using the equipment from the laboratory for testing electrohydraulic servovalves (figure 1), accredited by Romanian Register of Laboratories RENAR (Vasiliu D. and Vasiliu N. 2012). This way, any student from any Romanian or foreign university can study the behavior of these modern electrohydraulic interface devices in order to integrate them in complex control systems. The laboratory includes all basic types of modern general-purpose flow and pressure servovalves.

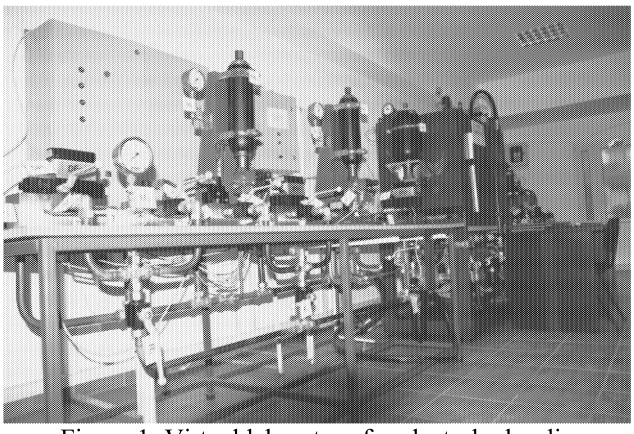


Figure 1: Virtual laboratory for electrohydraulic servovalves (partial view of the 35 MPa test line)

TEST PROCEDURES FOR ELECTROHYDRAULIC SERVOVALVES

Electrohydraulic servovalves are complex devices, which transform an electrical signal (voltage, current or digital pulses) into a hydraulic signal (flow, pressure or power). The power of the two signals is very different, but the relative amplitudes and the phases of the two signals must be as close as possible for any frequency. From the system

theory point of view, these devices are power amplifiers. The designer of a system including these components needs the steady state characteristics and the dynamic performances. These features are obtained by measuring and recording the servovalve input (the command) and the output - flow, pressure or any other equivalent variable. The international standards like ISO 10770-1 and the technical specifications of some high technical level manufacturers like MOOG Inc. were taken into account for designing the test rigs. For example, the instant flow was measured by means of a light low friction piston, considering the useful area, and the speed. The last one was found out using an LVDT, followed by the derivative of the output signal. The best option for getting high accuracy of the piston speed is to use an analog speed transducer, covering a long piston travel. This method is suitable for large flows and low frequency input signals, used to find the steady state characteristics. Great care must be shown to shield the transducers cables. Any external electromagnetic field is amplified by the derivative operation, introducing a strong noise in the data acquisition system.
A better solution for the same problem is the use of a speed transducer in order to measure the travel of the spool of the valve. The use of the position transducers is feasible for low frequency input signals, used in the laboratory for finding the steady state characteristics only. The input signal is a triangle wave with a frequency of 0.1Hz and an amplitude equal with the nominal input signal specified by the manufacturer. Figure 2 presents a typical response of a servovalve to such an input signal.

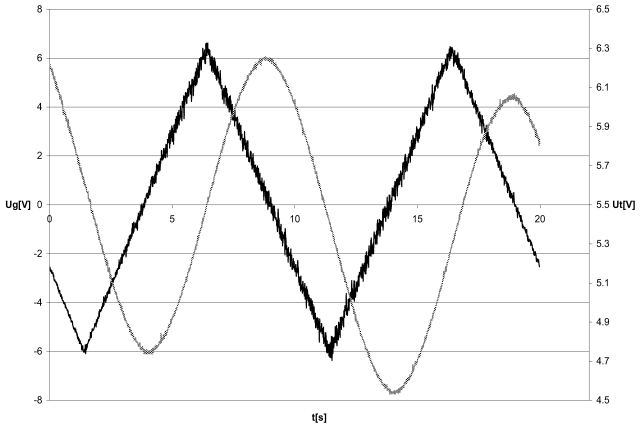


Figure 2: Input signal for the steady state characteristics and a typical response of a BOSCH proportional flow servovalve (no digital filter applied)

The servovalve dynamic behavior can be described by the aid of a speed transducer attached to the piston, or a metering orifice placed between the output ports. The last generation of servovalves allows for the measurement of the spool position. This opportunity was widely used in the new virtual laboratory platform. Figure 3 presents a typical frequency response of a solenoid DDV (direct drive valve). The spool travel for low frequency (about 1Hz) is taken as a reference one, and then compared with the travel for higher frequencies. Finally, the magnitude-frequency and phase lag-frequency diagrams were built. Figure 3 presents a typical frequency response for a modern flow servovalve tested in the virtual laboratory platform.

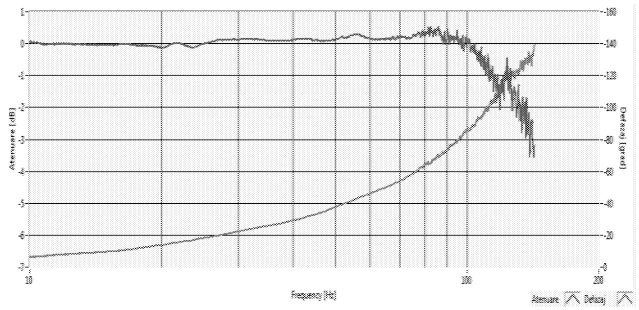


Figure 3: Typical frequency response of a BOSCH proportional flow servovalve (no digital filter applied)

The measurements can be made either with a multi-frequency chirp signal (figure 4) or with systematic increments of the frequency of the input signal.

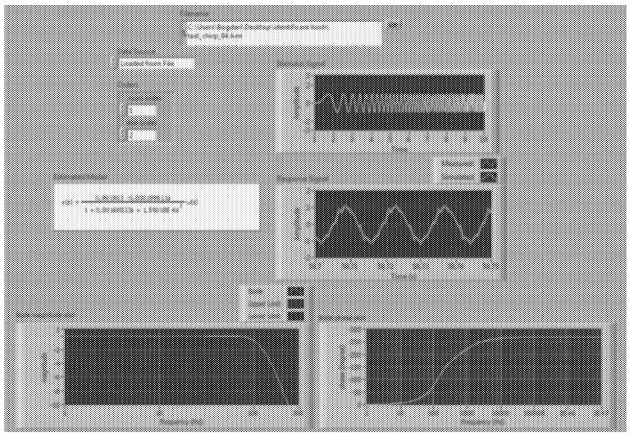


Figure 4: Identification sheet for a chirp signal applied to a servovalve

From the above test the Identification Toolbox from Matlab gives directly ω_n=645.6 s^{-1} and ζ=0.516 (slightly better than the manufacturer specifications).
For reasons concerning the flexibility of the program, both methods can be used in the platform. The user has the possibility to modify the minimum and maximum frequency for the test and the value of the frequency increment.

THE HARDWARE AND SOFTWARE STRUCTURE OF THE PLATFORM

Hardware

The test bench for electrohydraulic servovalves was designed in a modular and scalable manner. The test procedure described in the previous chapter had to be implemented in such a manner that multiple tests could be performed using the same components and various types of valves could be tested. The high-pressure test benches include a constant pressure fluid source (figure 5), which

supplies two hydraulic blocks with high purity hydraulic oil: one for high performance flow servovalves, the other - for direct drive proportional valves, both connected to a metering cylinder.



Figure 4. High pressure digitally controlled oil supply source (NAS 6 Shell TELUS 46)

The hydraulic diagram of test benches for steady-state servovalves behavior is presented in figure 4.

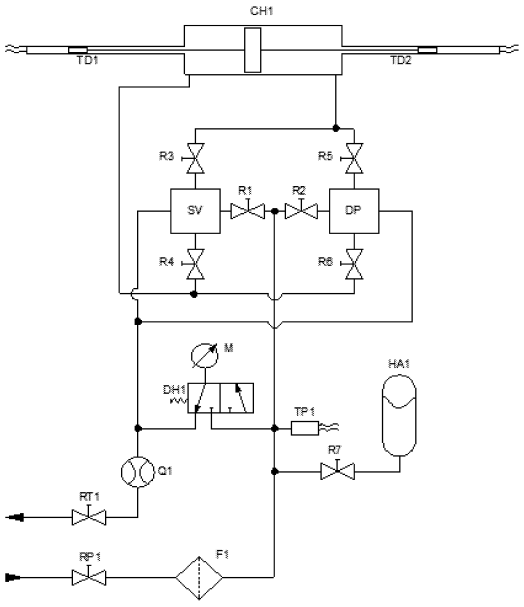


Figure 5: The structure of the test bench used for the virtual laboratory platform

Software

The control software of the platform was developed with LabVIEW program using National Instruments data acquisition boards and NI PXI computer platforms for web publishing. The PXI platform is an industrial computer build for measurements and control tasks. The PXI architecture brings into the industrial domain all the advantages of the PCI standards from the computer industry with enhancements regarding mechanical and electrical characteristics, reliability and ease of implementing data acquisition systems. A typical PXI system contains the chassis with its embedded controller and a series of interchangeable modules, each specialized in a certain task: data acquisition, signal generation, digital I/O etc. The PXI bus can be used to trigger all the modules, to synchronize the data acquisition with the computation of the performance curves and publishing the results on the web in "real time". The expression "real time" has to be taken lightly. Because of the limitation of the web technology a true real time, testing is not possible, but at low frequency, the system can be made to compute and display the performance curves one point at a time. This is especially useful in demonstrating the changes in behavior around the null point when implementing different control loops. The process is also time consuming for a simple steady state characteristics: the design target was to give the user the possibility of controlling all the test parameters; after pressing the start button the system returns the graphics. The software part of the platform is built in LABView and consists of four modules interlinked in the logic of two test programs: one for the steady state characteristics and other for the dynamic behavior. Figure 7 partially shows the software module used for controlling the signal generator. The signal generator program uses a standard method for creating a signal in LABView. It "writes" a waveform to the analog output buffer of a data acquisition board. The data acquisition module has two working states: data logging and system monitoring. The block diagram of the dynamic characteristics module uses a global variable to synchronize the signal generation with the data acquisition. The program has to include a data filtering and signal manipulation module, which is designed to cancel out the errors propagated by the derivative operation, used to compute the velocity of the piston. The user can change the parameters of the filtering modules, and the program can be utilized to both analyze acquired data on the spot or to analyze a previously logged measurement file.

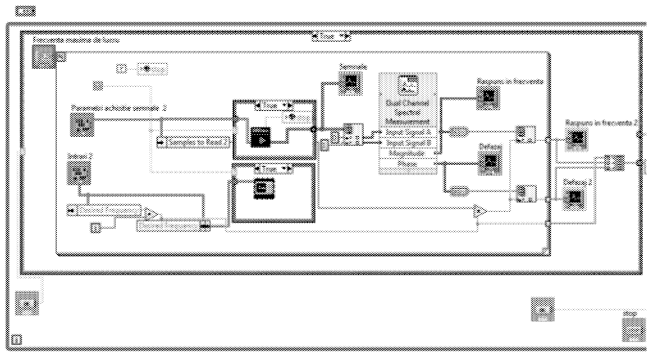


Figure 6: Block diagram of the module for computing dynamic characteristic (partial view)

EXPERIMENTAL RESULTS PRESENTATION

The above programs are published on the Internet using the LABView web publishing tools. The test bench was equipped with two families of modern servovalves: a high-speed SE2E type (figure 7) with additional electric position feedback and a D1FP proportional direct drive

proportional servovalve with electric position feedback (figure 8).

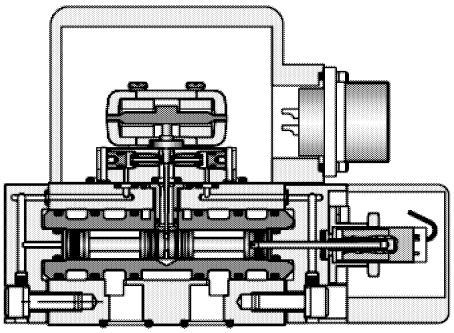


Figure 7: Main cut view of the SE2E with additional electric feedback servovalve (PARKER)

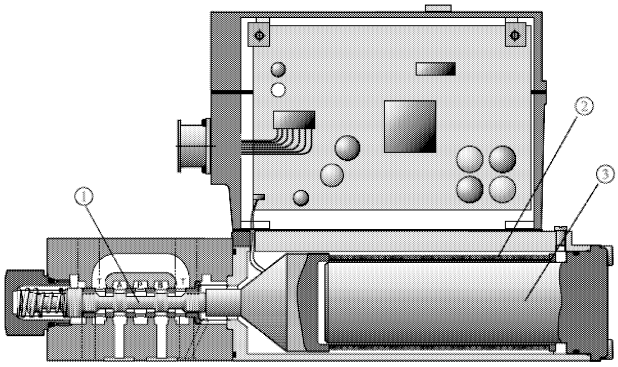


Figure 8: Cut view of D1FP proportional servovalve: 1-spool, 2-mobile coil drive, 3-permanent magnets and coils set (PARKER)

Figure 9 shows the *analysis display screen* for the steady state characteristic module corresponding to SE2E. This is a two stages, 4-way, flapper and nozzle style servovalve. A special jewel feedback design enhances durability and prevents ball glitch problems, which can occur in other types of servovalves. This valve is rated for 315 bar service, has on-board electronics, and electronic spool position feedback. These special features are improving the overall static and dynamic qualities of the servovalve. Besides minimizing valve hysteresis, the spool position feedback can be used as a safety-monitoring tool.

The first signal delivered by the test procedure shows a high degree of noise. The identification program displays both the filtered and unfiltered release of the graphs and the set of the original data taken into account for analysis (figure 10). The filters are giving a smooth curve with a very small hysteresis around the null point (figure 11). To build a linear model useful to describe the small amplitude dynamics of a servovalve it is important to know a proper value for the pressure gain, K_{PU}.

A special test module was devoted to this task. Two pressure transducers lock the output ports, and a small sine input signal is applied to the servovalve coils. Figure 12 shows a typical variation of the pressure gain for a standard servovalve.

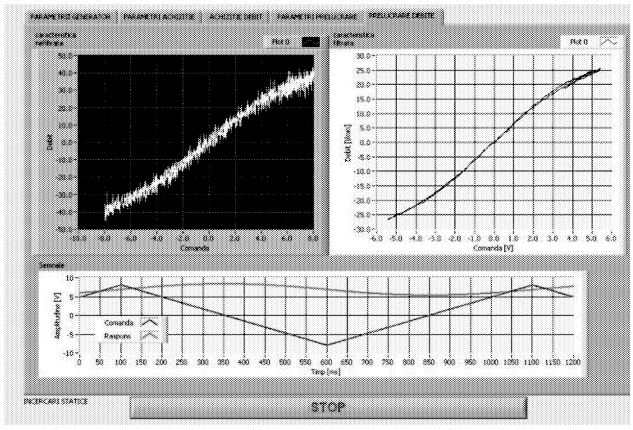


Figure 9: Analysis display screen for the steady state characteristic module

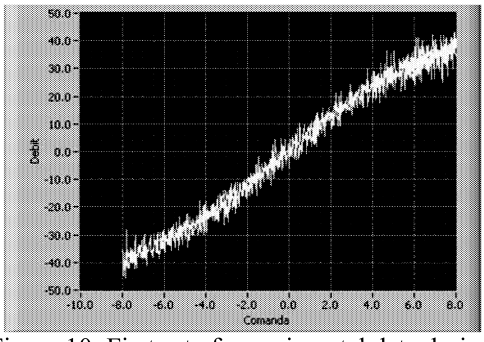


Figure 10: First set of experimental data during identification (before filtering) for SE2E

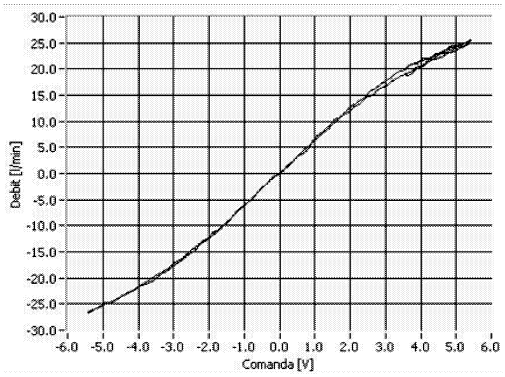


Figure 11: Final steady-state flow characteristics of SE2E

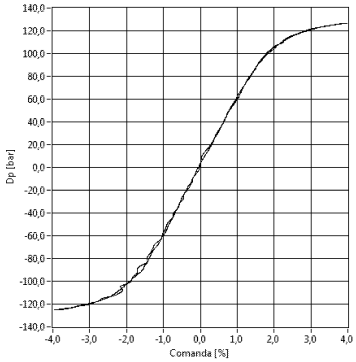


Figure 12: Pressure sensitivity of a proportional valve

The pressure sensitivity strongly depends on the supply pressure of the servovalve (figure 13).

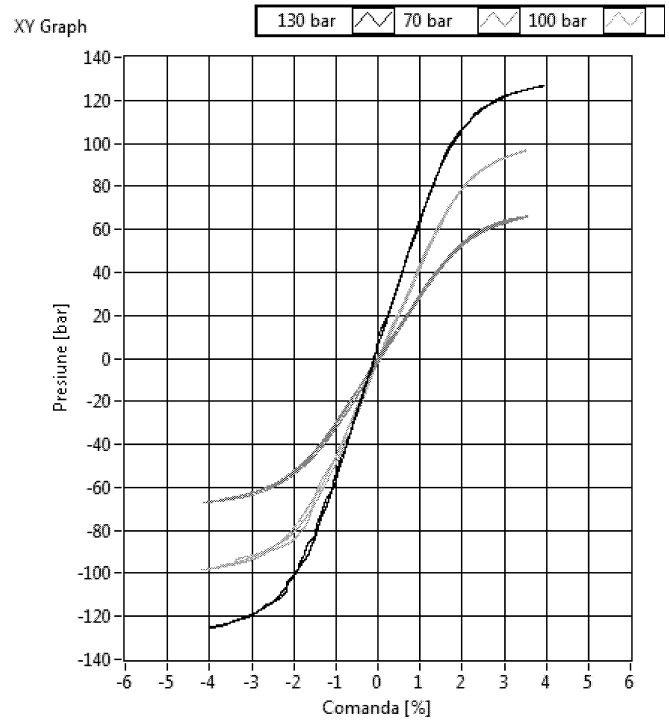


Figure 13: Pressure sensitivity of a servovalve as a function of the supply pressure

The accuracy of an electrohydraulic servomechanism strongly depends on the pressure sensitivity coefficient, K_{PU}. This quantity has a strong variation with the supply pressure (figure 14).

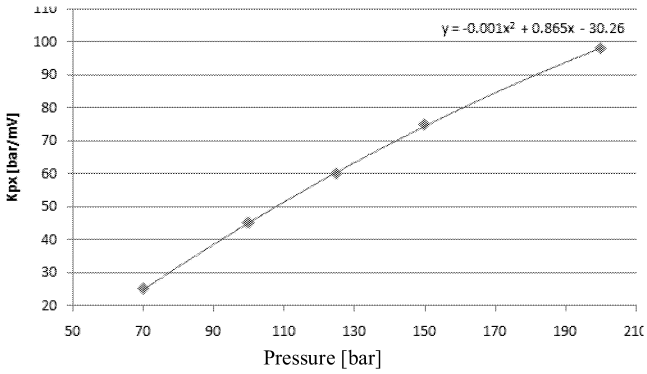


Figure 14: Pressure sensitivity coefficient K_{PU} [bar/mV] as a function of the supply pressure, p_s [bar]

The dynamic performance module was tested using the position of the spool as the output of the system. Figure 15 presents the dynamic response (amplitude and phase lag) for the same servovalve SE2E.

The static behavior of the D1FP proportional servovalve is nearly linear (figure 16). The dynamic performances (figure 17) are good enough for industrial applications. Web help can perform the whole identification process.

Using the interface of the ITFPS platform, the user can schedule the test, and then perform the static or dynamic test of one of the servovalves included in the lab. The user receives nearly in real time the image of the test bench (figure 18) and the final report with the experimental data.

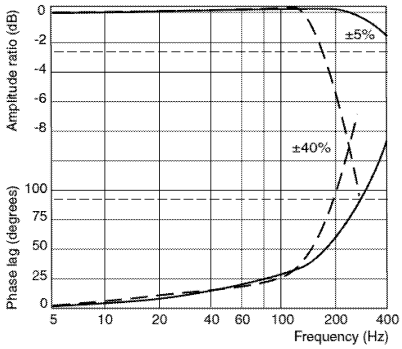


Figure 15: Dynamic performances of SE2 after filtering the chirp input signal

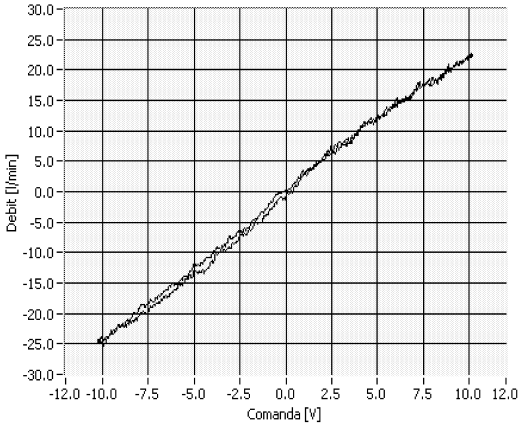


Figure 16: First set of experimental data during identification (before filtering) for D1FP

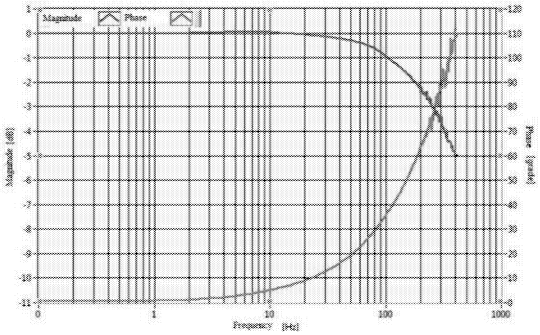


Figure 17: Dynamic performances of D1FP after filtering the chirp input signal (5% from nominal value)

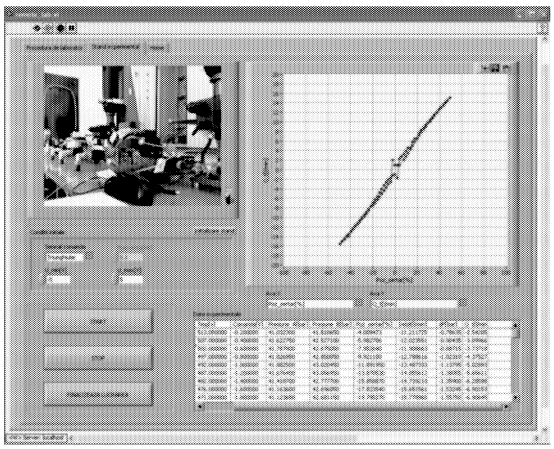


Figure 18: The image supplied by the web platform

CONCLUSIONS

The concurrent engineering design cycle includes modeling, simulation and test procedures that are capable of predicting, analyzing and optimizing the performance of multi-physics and mechatronics products. Any designer needs to take into account the interaction of different subsystems with sensors, actuators and controllers. The main objective of any engineer is to offer a high-speed optimal design. This target needs tools and interfaces which accelerate and optimize the design as AMESIM, but a complete test bench too. One of the ways, which can shorten the V cycle in any domain of mechatronics, is to use virtual laboratories, which allow anyone to test remotely a product, or to train him in the field. The experience gained by the Fluid Power Laboratory of the U.P.B. can be very useful for any category of specialists in control



Figure 19: Overall view of the dynamic test bench prepared for web test of the servovalves

ACKNOWLEDGEMENTS

The above research infrastructure (the only one in Romania) was financed (partially) by the MINISTRY OF NATIONAL EDUCATION through the Research Infrastructure Program, between 2007 and 2010. Other funds were obtained by the authors from research contracts with different state or private companies. SC CEROB SRL, an Applications Development Centre of PARKER from USA, manufactured the hydraulic infrastructure. NATIONAL INSTRUMENTS CORPORATIO made a strong infusion of software in the framework of a permanent co-operation with the Fluid Power Laboratory from the Power Engineering Faculty. Another important contribution came from LMS INTERNATIONAL CORPORATION (Belgium), a permanent partner of the above laboratory. The access to the platform utilities can be obtained using the site www.fluidpower.ro, and vasiliu@fluid-power.pub.ro e-mail address. Another way to access this platform is using the website www.piif.ro built within the framework of the Informatics Platform for Fluid Engineering - PiiF (POSDRU Project ID 61830) led by Professor Anton I. Anton from the Technical University of Civil Engineering of Bucharest.

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CONCURRENT ENGINEERING IN ENERGY APPLICATIONS

RT Simulation of Wind Power Station with NI LabVIEW

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KEYWORDS

Modeling and simulation, Doubly-Fed Induction Generator, Hardware-In-the-Loop, Model-In-the Loop, Rapid Control Prototyping

ABSTRACT

The paper presents a Real-Time MIL (Model-In-The-Loop) test approach for a DFIG (Doubly-Fed Induction Generator) wind turbine system by modelling the power grid, controller, wind turbine, drive and wound rotor AC induction machine, and simulating the wind signal. The practical target is to find the best way to extract as much energy as possible by optimizing the controller model behavior for various fluctuations of wind speed, sweeping from low wind speed when the turbine extracts less energy from the wind, and high speed when the turbine will limit its energy utilization to keep the extracted energy at the maximum allowable level.

INTRODUCTION

Wind energy is extensively used nowadays and new wind turbines are being installed at a very fast rate all around the world, wind energy being the energy source with the highest growth rate over the last couple of years. Most of the wind turbines produce energy over 25% of the time, with peaks during the winter due to stronger winds.
It has been estimated that the global technical potential of the wind energy can assure 5 times more energy than being consumed today, this degree of exploitation requiring 12,7% of the earth surface(excluding the oceans) to be covered with wind farms, with a density of 6 turbines/sq.km. Still, these numbers do not take into consideration the increase in performance of the wind turbines and the advancements of the technical solutions used harvest as much energy from wind, therefore reducing the number of turbines and making the concept of energy generation exclusively from renewable sources even more feasible.
At the end of 2013, Romania was occupying the 10th position in the European Union from the production of wind energy point of view. A total capacity of 106,000MW is currently installed in EU, Germany having the largest production of over 30,000MW, Spain with over 20,000MW, followed by Great Britain, Italy and France. On the 10th place, Romania has an estimated installed wind farms power of over 2,500MW, micro hydropower plants approx. 500MW, photovoltaic approx. 510MW and biomass-based energy production of about 43MW. The share of wind power in relation to the strength of electricity grids and other power plants is reaching levels where they may cause problems to system operators such as voltage variations, grid output unbalance and grid instability.

BACKGROUND

As Wind farms gain more percentage from the energy generation sources, they cannot be treated as VAR neutral or simply consumer, with control mechanisms that would simply disconnect them when system faults occur, but they require advanced local control, capable of providing reactive power when needed while being connected continuously to the energy grid and adapting to the requirements of the system. The wind turbine controller is a main component that implements increasingly complex logic for controlling both mechanical and electrical components in order to achieve wind farms seamless integration in the energy grid.

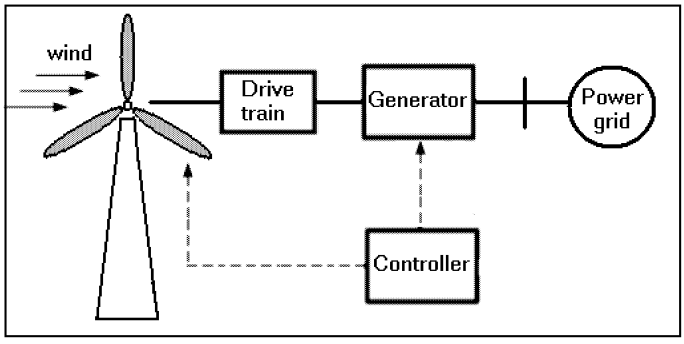


Figure 1. A wind power system

We can observe the main components of the system as being the wind turbine, the drive train, the generator whose two main architectures will be discussed in next chapter “Fixed Speed vs Variable Speed Wind Turbines” and the controller which controls both the generator and the mechanical components of the wind turbine. The wind

turbine converts the kinetic energy from the wind into mechanical energy, sent through the drive train. Further, the generator converts the mechanical energy from the drive train to electric energy, injecting it into the grid. The controller is the intelligent component of the wind turbine, having the ability to control both mechanical and electrical components. The controller is connected to sensors and actuators, having the ability to send intelligent commands to the actuators based on the sensors input.

The wind turbine mechanical components must extract mechanical power P_{mech} from the wind (Carlin et al. 2001; Mandic et al. 2011). The extracted mechanical power is defined as:

$$P_{mech} = 0.5\ \rho\ \pi\ R^2\ v^3\ C_p(\lambda,\Theta)$$

Here:
P_{mech} is the mechanical power,
ρ is the air density,
R is the turbine's radius,
v is the wind speed,
C_p is the power coefficient,
λ is the tip speed ratio,
Θ is the pitch angle.

The tip speed ratio is defined as:

$$\lambda = \frac{\omega_{mR}}{v}$$

Here
ω_m is the wind turbine rotation speed
R is the turbine's radius

We can observe that the mechanical power is directly proportional with the air density, the pitch angle, the square of the turbine's radius and the cube of the wind speed, offering us good information about how the positioning and the mechanical structure of the wind turbine can be optimized in order to harvest more energy from the wind. One important factor is the power coefficient described in figure 2 as a function of the tip speed ratio λ and the pitch angle Θ.

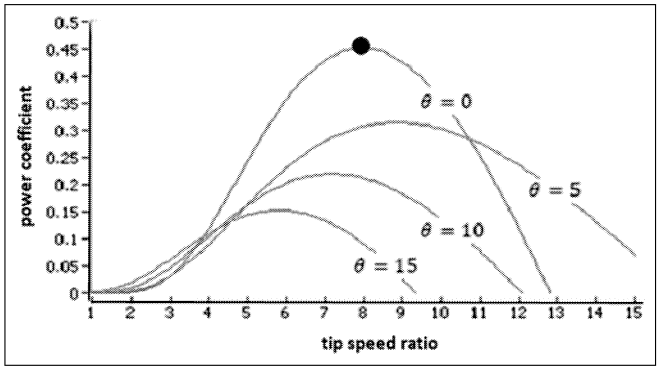


Figure 2. C_p as a function of the pitch angle Θ and of the tip speed ratio λ

The figure 2 presents the power coefficient for various pitch angles, relevant for understanding how the controller should command the wind turbine blades in order to achieve desired results. We can observe that the larger the pitch angle, the less energy is extracted from the wind due to smaller effective wind area. For one particular pitch angle, there is an optimal tip speed ratio that maximizes the power coefficient C_p. The red dot in figure 2 corresponds to the optimal wind energy utilization point.

FIXED SPEED VS VARIABLE SPEED WIND TURBINES

As the main goal of the mechanical components of the wind turbine is extracting as much mechanical energy from the winds kinetic energy, the need for designing variable speed wind turbines emerged, in order to utilize the wind turbine close to its optimum tip speed ratio.

In the case of fixed-speed wind turbines, there is only one wind speed where the tip-speed ratio is optimum. While the wind speed is clearly variable, using such fixed-speed wind turbines, the energy extraction from the wind will not be optimized as the wind turbine will be operating outside its optimum performance point.

The variable-speed wind turbines can produce power over a continuous range of rotor speeds, and by implementing an advanced controller, the turbine can be optimized so that it extracts more energy from the wind, operating a larger amount of time inside its optimum working point defined by the tip-speed ratio. Taking advantage of this optimized architecture depending on turbine aerodynamics and wind regime, allows the turbine on average collect up to 10% more annual energy. Considering a 20 to 30 year life of operation of a wind turbine, the increase of 10% reflects into significant revenue increase.

Moreover, a reliability comparison between the variable speed wind turbine and the constant speed wind turbine shows that variable speed design reduces mechanical stresses in the turbine's structure, therefore increasing the mechanical lifetime of the turbine.

DOUBLY-FED INDUCTION GENERATOR BASED WIND TURBINE SYSTEMS

Doubly-Fed electric machines are electric motors or electric generators that have windings on both stationary and rotating parts, where both windings transfer significant power between shaft and electrical system. Usually the stator winding is directly connected to the three-phase grid and the three-phase rotor winding is fed from the grid through a rotating or static frequency converter.

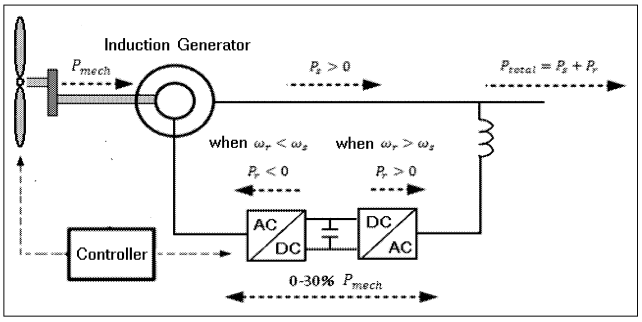


Figure 3. System Diagram of a DFIG-Based Wind Turbine System

Here:

P_{mech} is the extracted mechanical power

P_{total} is the total generated electrical power

P_s is the power from the stator to the grid

P_r is the power from the rotor to the grid

ω_r is the rotor rotational speed

ω_s is the synchronous speed.

Doubly fed generators are used in applications that require varying shaft speed in a certain range around the synchronous speed/frequency of generation. When $\omega_r > \omega_s$, the power flows from the rotor to the power grid. When $\omega_r < \omega_s$, the rotor absorbs the energy from the power grid. In the DIFG system, the energy is delivered to the power grid not only by the stator, but also by the rotor. Today doubly fed drives are the most common variable speed wind turbine concept. The DFIG-based wind turbine system is one of the main variable-speed wind power systems. When designing a wind power system controller, it must be optimized to keep the turbine's parameters close to their optimal functioning point, reflected by the optimal tip-speed ratio. As the controller operates over mechanical and electrical components, more than controlling the blades angle, it must control the generator so that it's compatible with the grid, which accepts only 50/60Hz fixed frequency, so the variable-speed, constant-frequency requirement is a big challenge for the wind turbine controller's design.

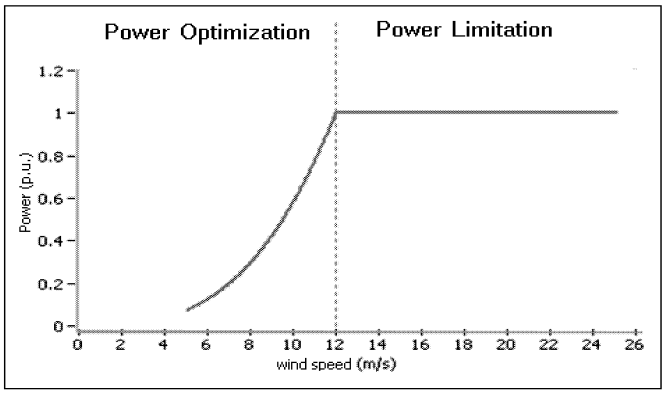


Figure 4. Power Generation Curve of a Wind Turbine

The wind turbines operate in 2 main regions in regard to the wind speed, the Power Optimization region and Power Limitation, regions divided by the wind speed of 12m/s. In the Power Optimization region, due to the slow wind speed, the wind turbine extracts less energy than its installed power. In this case, the controller has to send commands towards the doubly-fed induction generator in order to extract as much energy as possible from the wind, while keeping constant frequency output to the grid. In the Power Limitation region, the wind speed exceeded the value at which the turbine would generate its maximum allowable power. In this case, the controller has to send commands to control the pitch angle in order to limit the effective wind area resulting in limiting the rotational speed of the turbine, avoiding physical and electrical damage to the wind turbine power generation system.

USING NI LabVIEW CONTROL DESIGN AND SIMULATION MODULE

National Instruments LabVIEW is a tool used by researchers and scientists around the world to simulate, prototype and deploy control systems. The energy segment is a key focus industry National Instruments is focusing on in the last decade, optimizing the hardware and software tools to accelerate productivity. In order to ensure high quality in the deployed control systems, engineers and scientist must test and verify the control algorithms on a numerical simulation environment such as LabVIEW Control Design and Simulation Module. After performing such testing on modeling (Model in the Loop), the next step for deploying is HIL (Hardware in the Loop) where the model is deployed on embedded platforms and it's performances are being tested by Real-Time Hardware such as NI PXI, running mathematical models of the controlled plant, interfacing with the HIL-tested controller through real-world I/Os. Using this approach, the Real-Time OS is a key component assuring determinism in the behavior of the controller and of the simulated environment around it, while the flexibility of the NI modular platforms assure the wide spectrum of IO needed.

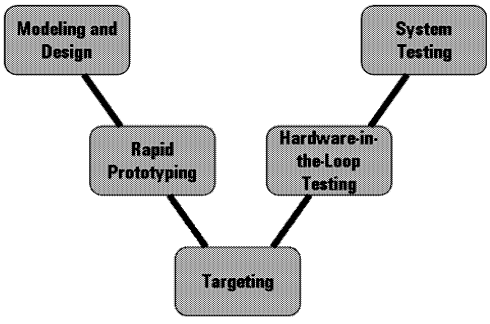


Figure 5. V diagram used to understand the controller design steps, from modeling to deployment & testing

CONTROLLER DESIGN AND VERIFICATION

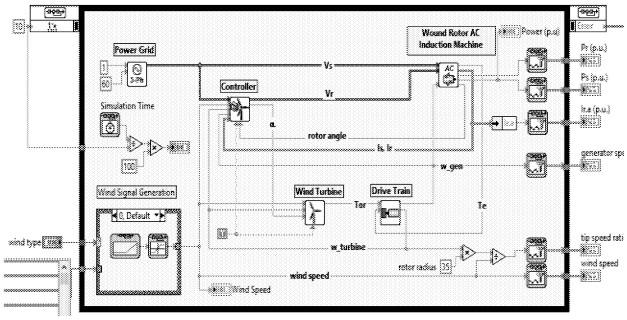


Figure 6. RT Simulation code of the Doubly-Fed Wind Power System in LabVIEW Control Design and Simulation Module

Figure 6 represents the code used for Real-Time, MIL testing of the controller by simulating the environment around it such as the power grid, the wind, the wind turbine mechanical components, the drive train and the DFIG (Pena et al. 1996). Figure 7 represents the two main parts of the controller, the master controller (figure 8) and the generator controller (figure 9).

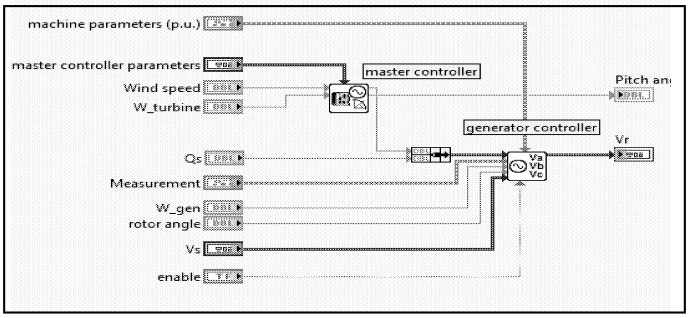


Figure 7. Architecture of the Controller

The controller is managing the behavior of the wind turbine power system by receiving information from sensors such as the rotational speed of the wind turbine from the drive train, pitch angle, electrical parameters of the DFIG, and electrical parameters of the power grid. In the power optimization region, it controls the power of the DFIG so that it keeps the optimal speed ratio, while keeping the generated power frequency constant, in phase with the power grid.

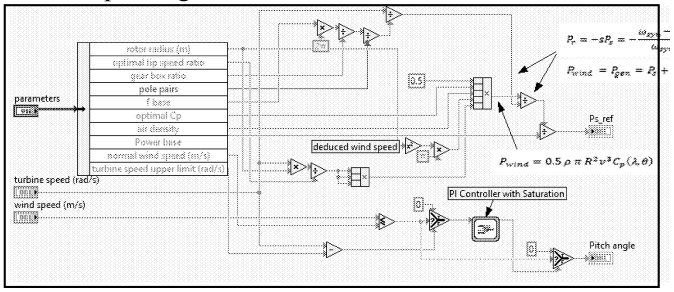


Figure 8. LabVIEW implementation of the master controller

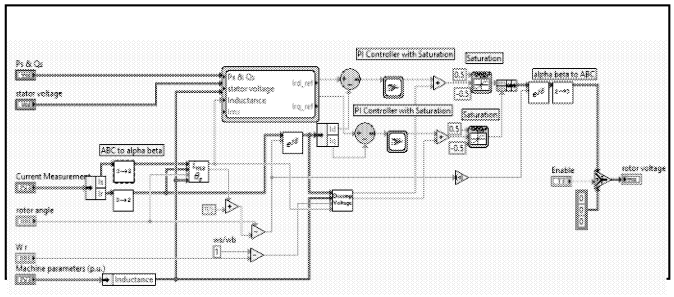


Figure 9. LabVIEW implementation of the generator controller

In the power limitation region, while assuring phase and frequency compatibility with the grid, it adjusts the pitch angle to limit the harvested wind power

The generator controller is in charge of accurately controlling the active power of the system. It adopts the stator flux oriented vector control strategy (see Annex A from Horwath Romania et al.).

CONCLUSIONS

Pr and Ps waveforms reflect the increase in generated power as the wind increases (see Annex B).

While in the Power Optimization region, the controller adjusts the rotational speed of the generator so that the controller can keep the tip speed ratio at its optimal value. The graph Ir.a (p.u.) shows how the rotor current frequency changes with the rotational speed of the generator. The graph Ir.a (p.u.) also verifies that the frequency of the rotor current is proportional to the deviation of the generator speed from the normal speed (1 p.u.). As the generator speed gets close to 1 p.u., Ir.a nearly becomes DC.

In the power limitation region, while assuring phase and frequency compatibility with the grid, it adjusts the pitch angle to limit the harvested wind power.

Once the wind speed reaches 12m/s we are in the Power Limitation sector where the controller reacts by controlling the pitch angle, limiting the tip speed for keeping the generator speed and the power coefficient close to its maximum allowable value.

Modeling and simulation tools such LabVIEW Control Design and Simulation Module can be used in order to validate controller behavior before deploying it into industry. The Real-Time deployment capability of NI LabVIEW, with the use of Real-Time module, allows easy migration from simulation/modeling code running on Windows machine to platforms running Real-Time OS, ensuring determinism and reliability in execution.

Using National Instruments software tools, SIL (Software In the Loop), MIL (Model In the Loop), HIL (Hardware In

the Loop), RCP (Rapid Control Prototyping), and Testing/Validation can be performed in the energy industry.The flexibility of MIL approach performed in this paper allows easy optimization of control algorithms, adaptation to various mechanical structures by changing/adapting the mathematical models of the involved components (Power Grid, Wind Turbine, Drive Train, Wound Rotor AC Induction Machine/DFIG) and the ability to test wind turbine behavior at various wind conditions. The presented simulation will be completed in the future by genetic algorithms similar with hydropower cascades (Piraianu, Vasiliu and Iana 2014). The RT simulation code from Annex C was already applied by the Fluid Control Laboratory of the University POLITEHNICA of Bucharest in the field of some future wind farms control from Romania.

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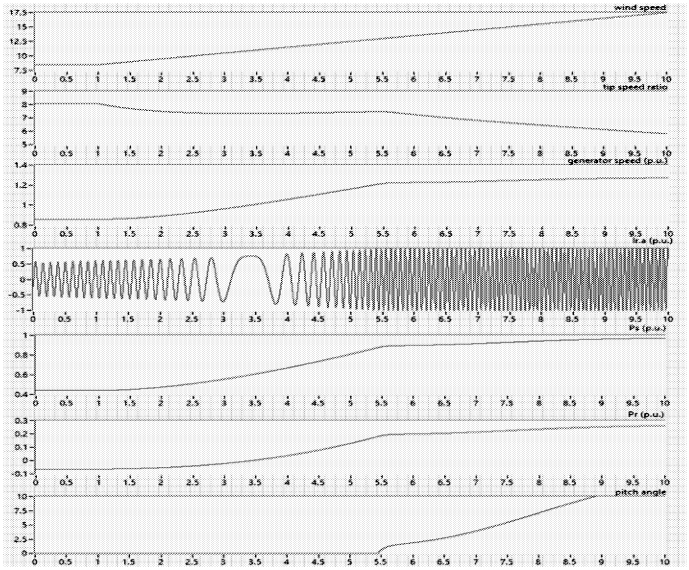
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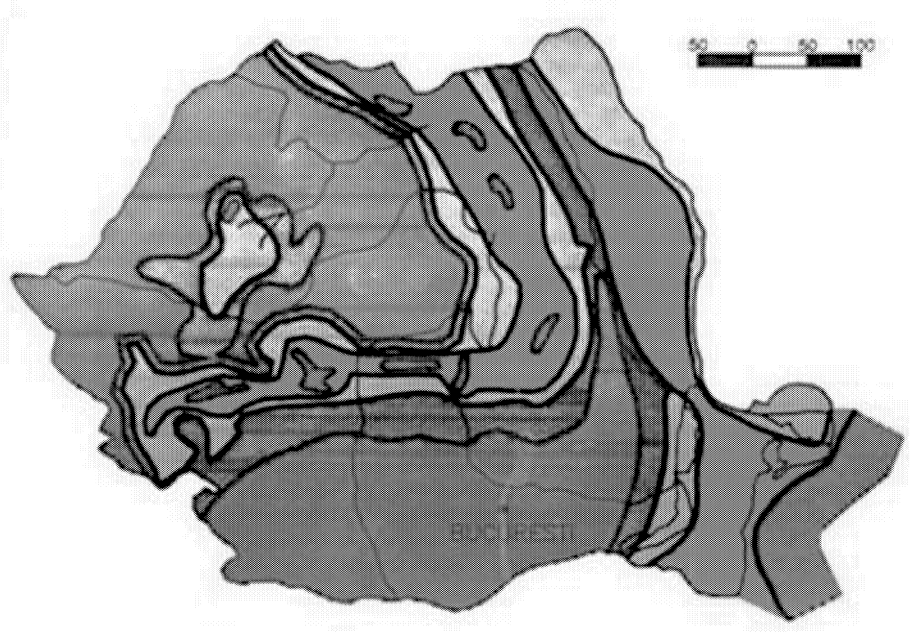
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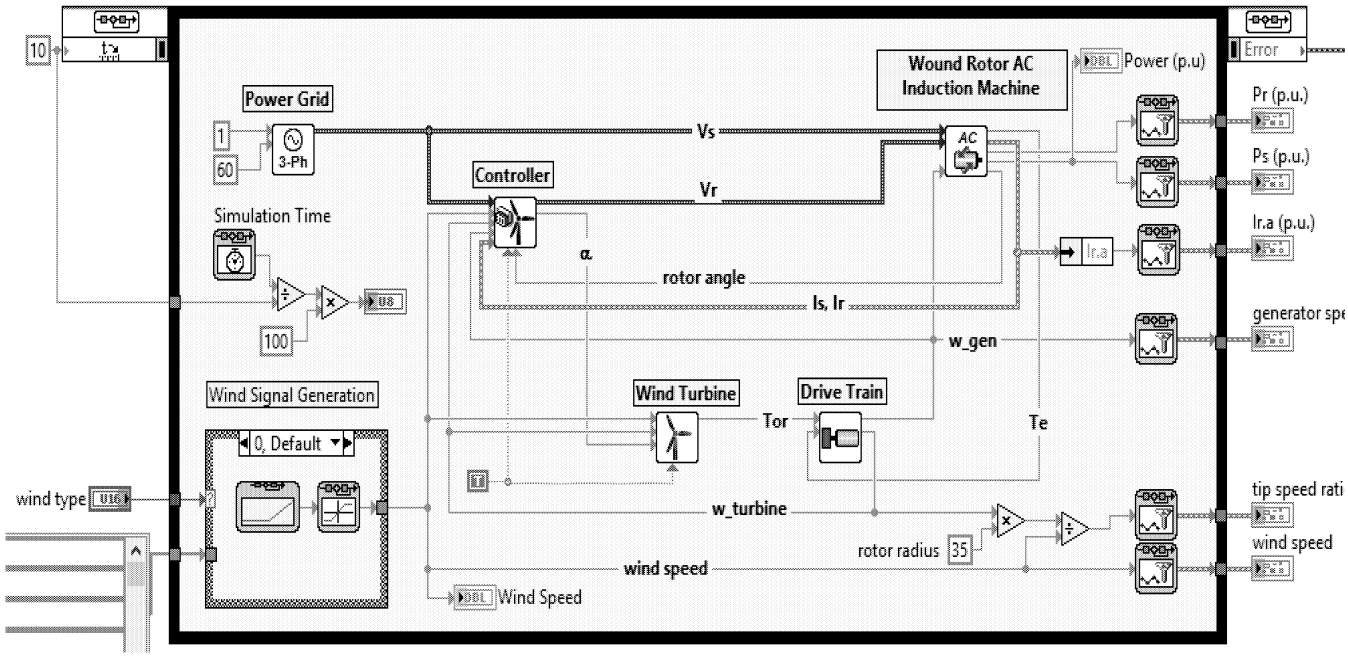


Appendix A. Graphical results of the implemented controller design



Appendix B. Romania's wind resources at 40 m height

Legend	Mountain		Open sea		Seaside		Open fields		Hills	
	m/s	W/m^2	m/s	W/m^2	m/s	W/m^2	m/s	W/m^2	m/s	W/m^2
	>11.5	>1800	>9.0	>800	>8.5	>700	>7.5	>500	>6.0	>250
	10.0-11.5	1200-1800	8.0-9.0	600-800	7.0-8.5	400-700	6.5-7.5	300-500	5.0-6.0	150-250
	8.5-10.0	700-1200	7.0-8.0	400-600	6.0-7.0	250-400	5.5-6.5	200-300	4.5-5.0	100-150
	7.0-8.5	400-700	5.5-7.0	200-400	5.0-6.0	150-250	4.5-5.5	100-200	3.5-4.5	50-100
	<7.0	<400	<5.5	<200	<5.0	<150	<4.5	<100	<3.5	<50



Appendix C. RT Simulation code of the Doubly-Fed Wind Power System in LabVIEW Control Design and Simulation Module

CONCURRENT ENGINEERING IN WIND TURBINES DESIGN

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KEYWORDS

Wind Turbines, Structure Durability, Multi-Body System, Noise and Vibration, MBSE

ABSTRACT

A major challenge to humanity in the 21st century is to supply a sustainable, clean and affordable energy in a safe manner. The interest for replacing fossil fuel in the energy mix partly by renewable energy sources, such as wind energy, has increased, especially in Europe. This trend is driven by the following motives: pollution aspects, the dependence of the European economy on the import of fossil fuel, the fossil fuel has limited resources on earth and the renewable energy can be considered as a durable alternative. A consistent modeling and simulation approach is presented in order to describe the real behavior of wind turbines. Two main concurrent engineering approaches are considered: Hybrid Engineering and Model-based systems engineering (MBSE Engineering). The Hybrid Engineering allows simulation and optimization of the performance of mechanical systems for structural integrity, noise and vibration, acoustics, system dynamics and durability, from the initial concept to the complete modeling and simulation of components and the full wind turbine. MBSE Engineering enables creation and run of multi-physics simulation models in order to analyze and design the associated complex control systems. The following aspects related to wind turbines design process are briefly presented: Multi-body simulation, Durability simulation, Acoustics simulation, MBSE.

INTRODUCTION

In the Traditional Design, sometimes termed as Serial Design, once the design is done, all of the departments that are involved in the product realization are expected to follow it although they have very little input in the design of the product. Very often, the design team in the traditional model does not have the knowledge and the skills to make a product that will be functional, of high quality and easy to manufacture.
Concurrent Engineering, sometimes called Simultaneous Engineering or Integrated Product Development (IPD), can be defined as a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support.
This approach intends to force companies to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements.
Concurrent Engineering provides many benefits over sequential engineering, including lower manufacturing and production costs, improved quality of resulting end products and increased accuracy in predicting and meeting project plans, schedules, timelines, and budgets. Concurrent Engineering is an evolving process that requires continuous improvement and refinement. This continuous improvement cycle consists of planning, implementing, reviewing, and revising. The process must be updated and revised on a regular basis to optimize the effectiveness and benefits in the concurrent engineering development process (see Figure 1).

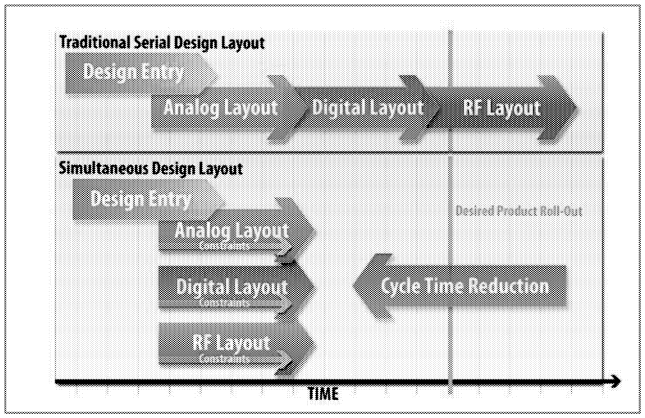


Figure 1: Traditional vs. Concurrent Design Process

A classical design process concept is the V cycle. From a definition of client requirements, the design specifications will be issued at three levels, following a down cascade from upper level conceptual model to component design and detail specification.
Having realized all design specification, the second part of the process will be to integrate components into sub-systems, to validate the technical choice of the previous path.
The CAD & document driven design process is a Traditional design process in which products were design and manufacturing according to the sequential engineering methods, where people from different departments work one after the other on successive phases of development. The design of the different systems in the product is performed in separate times.
No interaction between mechanical, electrical, hydraulic aspects, on one side, and control models, on the others side, was considered.
The MBSE driven design process on the other hand allows the integration between the design Vs enabling upfront product architecture optimization and reducing development time with 30 to 40% (see Figure 2).

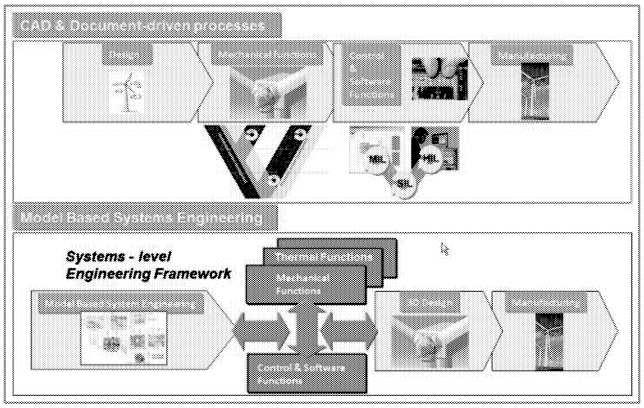


Figure 2: CAD driven vs. MBSE driven design process

Furthermore, MBSE enables the “mock-up” approach that wraps together 1D and 3D, Test and Control solutions (see Figure 3).

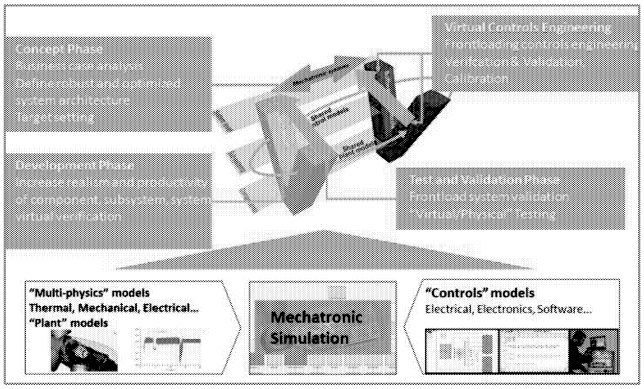


Figure 3: MBSE, bridging the multi-physics, electronics and controls

MBSE allows for a wider range of ideas and solutions to be explored, validation of the technical feasibility, reduction of the design cycle by virtual integration and reduction of costs with fewer physical prototypes.

HYBRID ENGINEERING APPROACH

Nowadays, manufacturers are pressured to deliver more complex products with increased quality in shorter development cycles. Engineering the performance of mechanical designs with traditional test only - based development processes is no longer an option. The only valid alternative is evaluating functional performance attributes on a virtual prototype, employing previously used, tested and tried methodologies.
Any use of computer software to solve engineering problems is termed as Computer-Aided Engineering (CAE). A typical CAE program is made up of a number of mathematical models encoded by algorithms written in a programming language. The natural phenomenon being analyzed is represented by an engineering model: a geometric model describes the physical configuration.
A wide range of technologies are used during different design phases in simulation driven product development, including structural MBS & finite element analysis, acoustics, crash analysis, fatigue and failure analysis, and computational fluid dynamics, see Figure 4.
The main aspects of the hybrid approach, simulation and testing solutions, can be grouped as follows:
- 3D Virtual simulation - MBS & FE: gear modeling; system modeling for noise, vibration and durability; fatigue life prediction;
- 1D Multi-Domain simulation: electric architecture comparison; control strategies studies; power grid connection optimization;
- Testing solutions: vibro-acoustic measurement and analysis; driveline operational measurements; gearbox noise path identification.

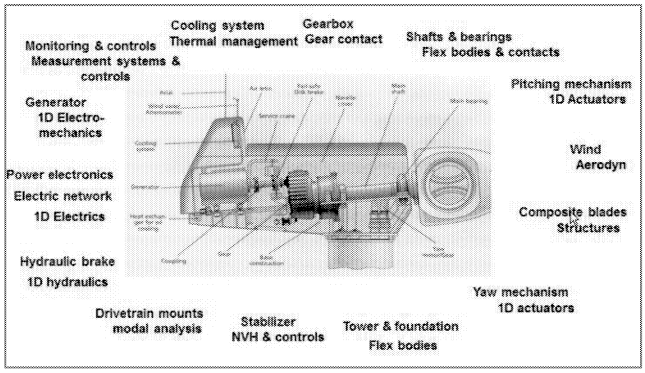


Figure 4: Full and Multi-attribute simulation (mechanics, actuators, durability, acoustics, and controls) of a wind turbine

Multi-body simulation of the wind turbine drive train

Multi-body simulation is used to assess the structural reliability of the gearbox and to make sure it resists the

extreme and unpredictable loads from the wind and does not break under high or concentrated stresses.
The drive train has one main bearing integrated in the gearbox carrying the wind turbine rotor. The generator is a doubly fed induction generator and the gearbox design is a combination of two planetary stages with one high-speed parallel stage.
The wind turbine rotor is connected to the planet carrier of the first planetary stage. This stage has spur gears and its ring wheel is fixed in the gearbox housing. This housing is assumed to be rigid as well as its connection to the bedplate.
The second gear stage in the gearbox is a helical planetary stage. The sun of the first stage drives its planet carrier and its ring wheel is fixed in the gearbox housing. The pinion of this stage rotates at the speed of the generator. A brake disk is mounted on this output shaft and a flexible coupling connects it with the input shaft of the generator.
In a standard 1.5MW wind turbine the huge input torque of around 1000kNm coming from the blades rotating at 15 rpm has to be transferred to realize a gear ratio between input and output shaft of more than 100 in order to match the rotational speed needed to generate electricity from the generator. Typically, this is done through a 3-stage gearbox design, a first stage with planetary gears (offering a large gear ratio and a low weight of the gears) and two subsequent parallel gear stages. Next to the gears themselves, the bearings have to be modeled in detail because of the very high loads they support and their key impact on the overall reliability of the wind turbine.
To model the gears meshing inside the gearbox, which is one of the main excitation sources in the wind turbine, two main approaches are available:
- An analytical one, based on the CAI/ISO methodology for meshing stiffness calculation;
- An advanced, discrete method, which combines a series of FE, cases for calculating teeth deformation and an analytical definition of the tooth micro-geometry.

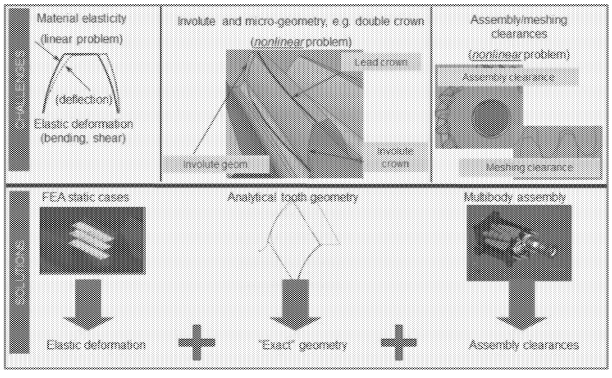


Figure 5: Advanced method for contact force calculation

Wind turbine acoustics optimization

The noise wind turbines generation is influenced by many factors, including blade size and design; drivetrain operation as well as the orientation, force and turbulence of the wind. There are two types of wind turbine noise:

a) *Blade aerodynamic noise.* This has a broadband and low frequency spectra. It depends on blade aerodynamic design, on atmospheric wind turbulence and on blade operating conditions.
b) *Rotating machinery noise.* This has a deterministic noise spectrum (RPM) and can be divided in two principal groups:
• Airborne noise represented by direct acoustic radiation from machinery housing (gearbox, generator and accessories);
• Structure borne noise, see Figure 6.
Specific tonal noise components occur because of dynamic forces that come into play inside the gearbox (teeth meshing), the generator (electro-mechanical poles interaction), and system hydraulics equipment.
The noise generated by driveline rotating machinery also propagates directly through structural noise paths. These dynamic forces cause local housing surface vibrations, which distribute the noise to the surrounding area through radiation.

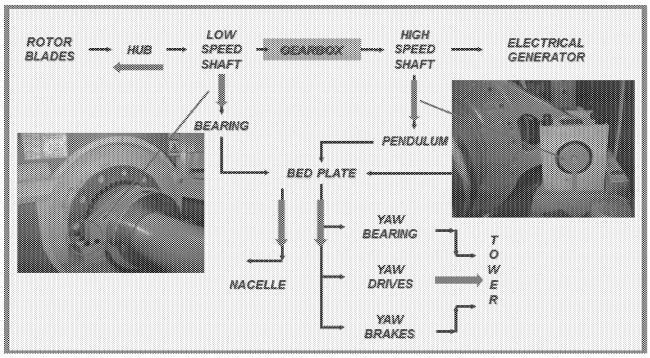


Figure 6: The propagation of the driveline rotating machinery noise through structural path

Based on the structural full-system FE model, a Boundary Element (BE) model of the wind turbine through a dedicated "skinning" procedure is derived. The acoustic BE model makes it possible to simulate the acoustic power generated by the wind turbine through local surface vibrations of various system parts. This information serves as input for the Acoustic Transfer Vector (ATV) method that accurately and effectively translates the acoustic power into far field noise emissions, Figure 7.
Transfer Path Analysis (TPA) is used to evaluate the contribution of the different structure borne and airborne transfer paths between a given source and target locations. TPA uses transfer functions between the target and the forces at all considered transfer paths and combines these with estimates of the forces acting on the considered paths during operational conditions or transient operating conditions. These operating forces are either available as experimental data or have to be determined indirectly. One of the major advantages of this deterministic acoustic simulation approach is that it supports different kinds of analyses that provide detailed insight into particular noise sources. Through post-processing, it is possible to trace the modal contribution of specific system parts, or analyze the

effect of individual panels and loads on overall noise radiation. The engineering information resulting from these investigations is vital for driving development improvements and new wind turbine development. Deterministic acoustic simulations were performed up to a frequency of 200 Hz, which allowed significant structure-borne noise phenomena to be traced and tackled with sufficient reliability.

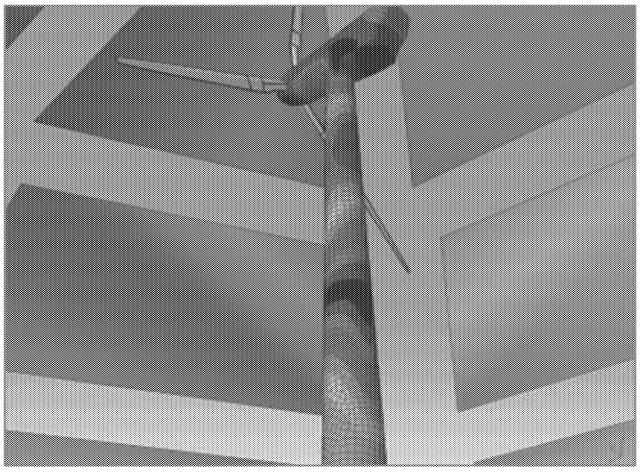


Figure 7: ATV volume velocity distribution for a wind turbine, the tower is one of the main acoustic emitters

MBSE ENGINEERING APPROACH

Model-Based Systems Engineering (MBSE) is defined by the International Council on Systems Engineering (INCOSE), as the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases, Figure 8. Mechanical system designs, as of wind turbines combine a number of subsystems of different nature. Mechanical, thermodynamic and powered actuator subsystems and the electronic controllers are all combined into an intelligent system. The engineering of such intelligent systems requires a multi-domain simulation approach that combines mechanical, thermal and electronics in an integrated simulation process in order to predict with accuracy the behavior of the different subsystems.

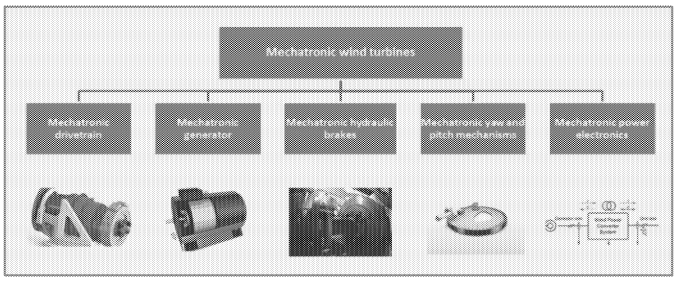


Figure 8: Overview of the MBSE based design for wind turbines

Through MBSE interconnection, two objectives are sought after. First is to perform systems engineering based on the multi-physics "plant" model.
The second is to perform control engineering, including a realistic model of the systems "plant".

Multi-Physics PLANT models

To address the multi-physics part of the MBSE process, software packages like LMS AMESIM provide a wide range of plant models ranging from simple hydraulics and pneumatics, up complex electrical motors/internal combustion engine and vehicle dynamics, see Figure 9.

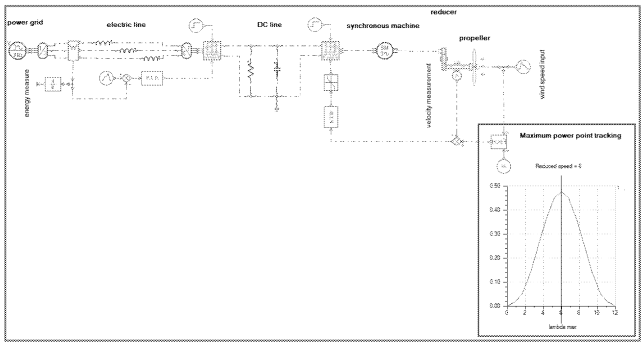


Figure 9: Multi domain, system level model of a wind turbine

In the above exemple, the blades model (on the right side, "propeller") transforms the wind energy into mechanical energy on a rotating axis.
The wind turbine's efficiency, which is of interest, in this case, depending on a reduced speed parameter, is integrated in the model. This efficiency has a bell shape curve. When the wind speed is low, the turbine is not efficient. If the turbine rotates too fast, its efficiency is not optimal either.
For the gearbox (in green, "reducer"), a wide range of modeling levels are available in LMS AMESIM: from a simple ratio, to the possibility to simulate the teeth backlash with variable contact stiffness.
For the simulation of the electrical components such as the generator, the inverter (orange) and the power grid, Electrical Basics Library and Electric Motors and Drives Library can be used.
The design of control laws could be done directly in AMESim, or using Matlab/Simulink and coupling the control model with AMESim.
As an exemplification to the possible complexity of the plant models, the Power Train library in AMESIM provides gear train models having:
- Simple Transformer ratio: gear contact ideal without any stiffness and any losses and the equations correspond to these assumptions considering only a transformer ratio and handling with causality and sign convention aspects.
- Constant or variable losses: constant efficiency, variable losses defined with tables torque & velocity absolute values as inputs.

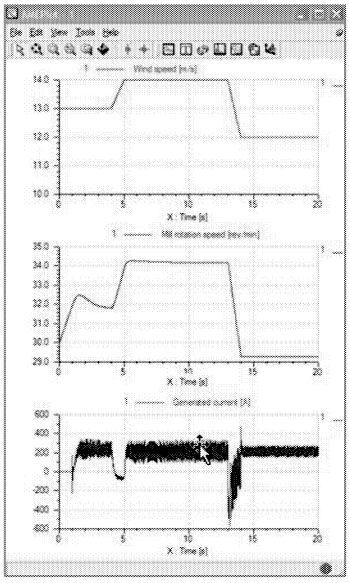


Figure 10: Additional results available linking wind speed to main shaft rotational speed and generator current

- Calculated losses based on gear geometry: gear contact geometry is well known, gear geometry is partially known.
- Clearance and contact stiffness: accounts for a fix value of the contact stiffness and damping.
- Variable contact stiffness: accounts for non-linear contact stiffness determined by Hertz theory.

As previously mentioned "What if" scenarios are easily investigable by system level approach.

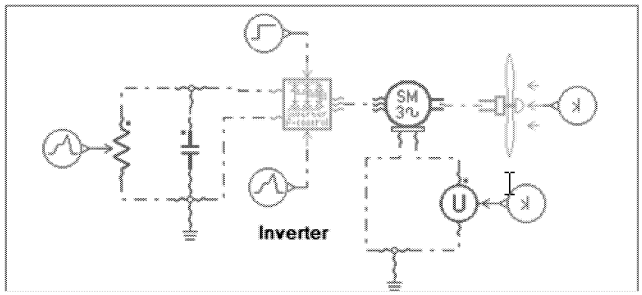


Figure 11: Synchronous machine connected to DC line with local load

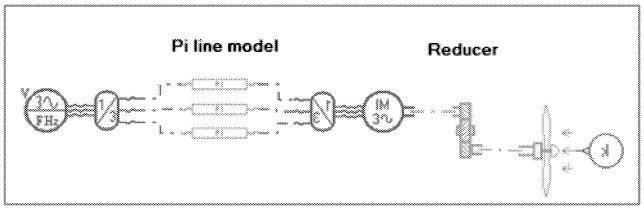


Figure 12: Induction machine directly connected to the power grid

In the above examples, models allow the choice between several technical architectures: a synchronous machine or induction machine, but also the use of a mechanical reducer or machine with high number of pole pairs.

When the architecture is selected, the model helps to answer "What if" questions: test connection with power grid, online failure detection and study control laws in order to optimize energy management.

Controls Design/Validation

Traditional Design and Validation methods for controls rely mostly on physical prototypes, hence is time consuming and expensive. Model Based Systems Engineering enables early verification and validation thus improving quality and shortening the development time, (Figure 13).

Simulation based Verification and Validation strategies involve simulating controller model or code and observing the behavior to identify errors, meaning:

- functional validation can determine whether the control system behaves as expected/desired.
- structural verification can ensure that the software does not perform any unintended actions.

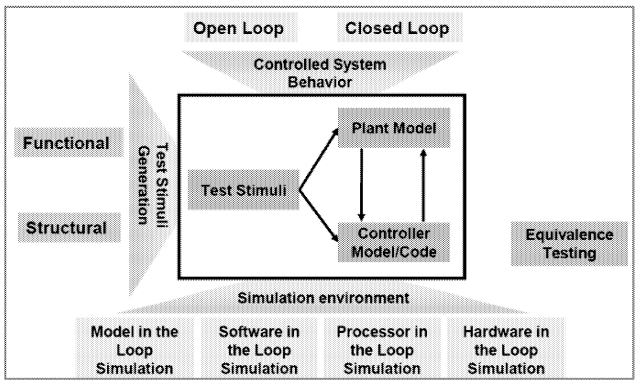


Figure 13: Overview of the Design and Verification techniques

From the controlled system standpoint, two alternatives may be considered:

- Open loop case: which is used for first level testing when the controller code is changing rapidly during the initial development stages. It allows testing the behavior of the controller in the presence of the failures
- Closed loop: in which the controller's functional behavior is verified using feedback from controlled system. It requires plant models sufficiently detailed to accurately represent the controlled system's behavior.

From a standpoint of the simulation environment in which the controller is being tested, the alternatives are grouped in the xIL methods (Figure 14).

Model in the Loop (MiL), (Figure 15), defines a simulation involving controller model and controlled system model in a desktop. MIL traits:

- Very useful for testing the control algorithm alternatives.
- Can be performed early in the control development process to identify unfeasible designs and hence saving a lot of time designs and hence saves lot of time.
- High fidelity plant models can be used as the simulation is non-real time.

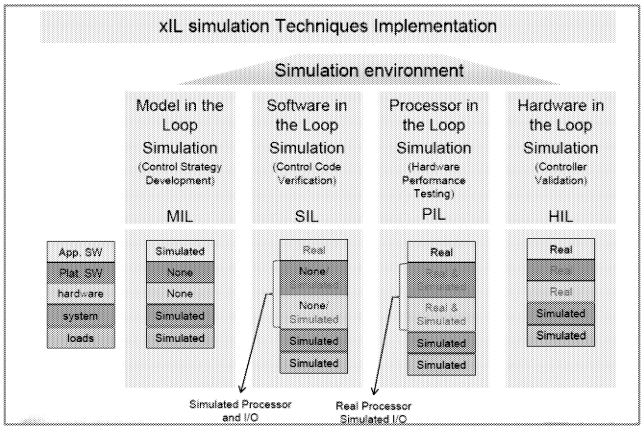


Figure 14: Overview of the xIL methods

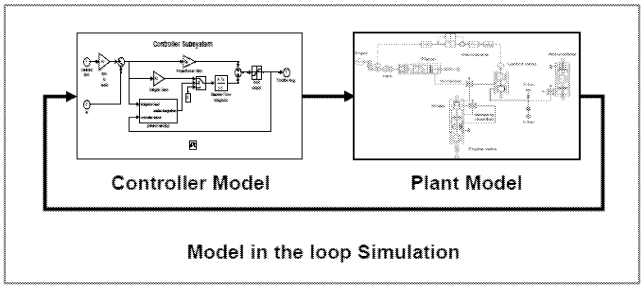


Figure 15: MIL schematics

Software in the Loop (SiL), Figure 16, defines a simulation involving controller code and controlled system model in a desktop. SIL: traits:

- Useful in identifying implementation errors
- Can be performed before the availability of controller hardware.
- High fidelity plant models can be used as the simulation is non-real time.

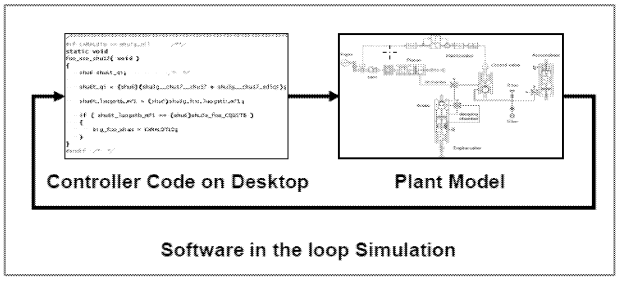


Figure 16: SIL schematics

Processor in the Loop (PiL), Figure 17, defines a Co-simulation involving controller code on the target processor and controlled system model on a desktop. PiL traits:

- Controlled system model and target exchange data using standard communication protocols.
- Useful in identifying target processor related implementation errors (like memory limitations).
- High fidelity controlled system models can be used as the simulation is non-real time.

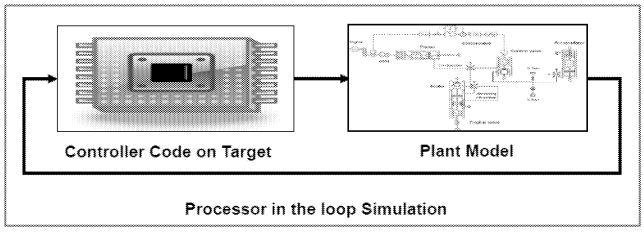


Figure 17: PiL schematics

Hardware in the Loop (Figure 18) defines a real time co-simulation involving the controller code on the target processor and controlled system model on a real time computer. HiL traits:

- Controlled system model and ECU exchange data using IO channels available in the ECU.
- Useful in identifying both IO & processor related implementation errors.
- High fidelity controlled system models requires high-end computing machines to simulate these models in real time.
- Very useful to test controller behavior under extreme operating conditions.

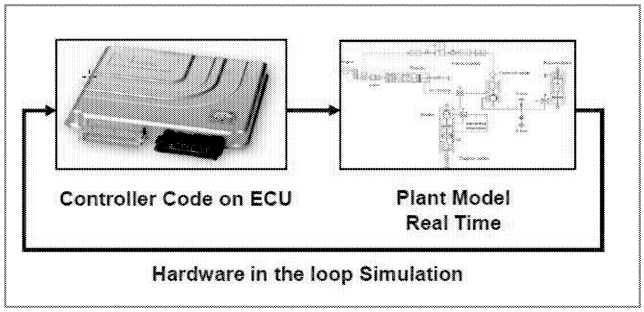


Figure 18: HiL schematics

CONCLUSIONS

Increasingly development of the production of electricity using wind resource is determined by a balanced relationship between expectations and requirements for wind turbines. There are customer and manufacturer expectations. As customer requirements can be listed: site integration and environmental friendly, wind park profitability, low annual cost of energy, guaranteed reliability and a long term service agreements up to 20 years. Manufacturer's expectations are: high performance and reliability, minimal development cost, minimal production cost and environment friendly. These expectations generate the following engineering challenges: extreme dimensions, limited yearly production rates, high cost of physical testing and high accuracy of CAE/MBSE.

Efficient simulation permits to simulate all events in batch and to identify the important loading. Also, it is possible to analyze design parameters sensitivities to performance and to optimize the design and refine the structure. At the end it the performance of the whole installation is validated.

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CONCURRENT ENGINEERING APPROACH OF THE ELECTROHYDRAULIC CONTROL SYSTEMS FOR POWER PLANTS

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KEYWORDS

Concurrent engineering, modeling, simulation, identification, redundant electrohydraulic control systems

ABSTRACT

This paper presents a concurrent engineering approach of the synthesis of the modern electrohydraulic digital control systems. Three close connected technological major achievements completely changed the synthesis process of the electrohydraulic control systems: a) the availability of a new generation of high-speed electrohydraulic industrial servovalves, with a higher security regarding the oil quality; b) a strong progress in the versatility of the industrial process computers; c) a fundamental changes in the structure of the sensors, which turned them in intelligent devices. The above facilities now allow the designer to concentrate on the new systems performances, using modern tools: modeling, simulation, and experimental identification. This activity can occur *in parallel* with the technological design of the whole control system. A new feature of the concurrent engineering is the possibility of using different level of redundancy without affecting the main technological design. The need of digital redundancy comes mainly from the need of an absolute accuracy in processing the information inside any digital control system. This paper presents a manner of solving this problem by the aid of a Hardware-In-the-Loop simulation of the speed and pressure digital control system for a high head Francis turbine. The proposed procedure can be implemented on any dedicated industrial process control hardware.

INTRODUCTION

Electrohydraulic driving and control systems are frequently used in the structure of critical systems, in fields like aerospace, military and power engineering. Any eventual malfunction of such system may lead to a catastrophy resulting in loss of human life and/or singificant economic damage. In order to insure proper fault tolerance, the hydromechanical actuators and the control units are often doubled or tripled.
In the field of hydraulic and pneumatic driving systems, the recent literature describes several redundancy techniques, like: passive redundancy, active redundancy and damage compensation techniques. In the case of passive redundancy, one actuating system is functioning at a given time only. In case of main system malfunction, the backup channel is activated. The detection of any malfunction can be achieved by monitoring the active system. For this type of redundancy the backup system has a higher functional safety than the main system, and the monitoring system has a very high standard of reliability. This kind of systems have several disadvantages such as: the time needed to activate the backup channel; the electrohydraulic motors used to transform the hydraulic energy into mechanic energy need to have similar size in order to allow the backup system to develop the necessary force or torque. In case of electrohydraulic systems using active redundancy, two systems operate simultaneously, as in figure 1.

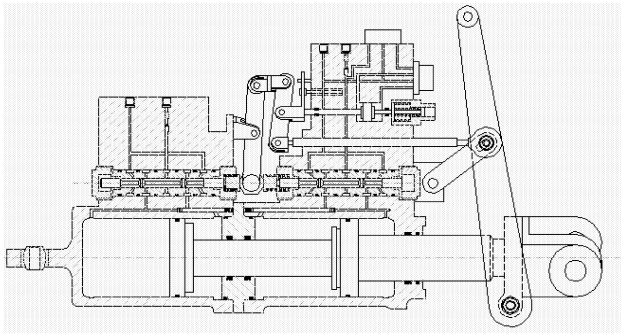


Figure 1: Double input redundant electrohydraulic servomechanism (DOWTY 1971)

These systems share the load, the output achieving a sum of forces. In case a malfunction occurs, the damaged system is disconnected and the task of actuating the process is taken over by the valid one.

MODERN ELECTROHYDRAULIC CONTROL SYSTEMS USED IN POWER ENGINEERING

Redundant electrohydraulic systems are used in applications where the costs of the system going temporarily out of use is greater than the cost of implementing a redundancy solution. A field where the safe functioning of actuating systems is a basic necessity is the field of hydropower. Malfunctions in the turbine speed governors can cause damage to the hydropwoer unit itself and even alterations of the quality of electrical power

supplied to the system, with serious consequences. Figure 2 presents the principle scheme of a new hydraulic turbine speed governor patented by Vasiliu N. and Calinoiu C. in 2003. In the global power system, the balance between production and consumption is achieved with the aid of power and speed governors static droop. By the combined action of interconnected generators a high level of consumer safety can be achieved as a stationary value for system frequency can be set, and disturbances have little effect. Power systems mainly use two control strategies: primary tuning and secondary tuning. Both strategies require speed and power governors for all power units but the main role is held by the hydropower units which can react quickly in case of local or global variation of system load (frequency).

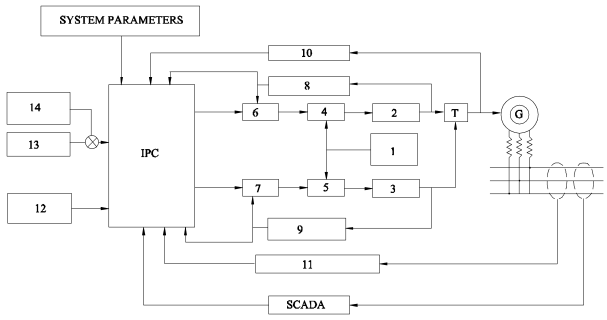


Figure 2: Principle scheme of a modern digital speed governor: 1-hydraulic power suply; 2-wicket gates hydraulic servomotors; 3-runner hydraulic servomotor; 4, 5-servovalves; 6, 7- analog servocontrollers; 8,9-position transducers; 10- speed transducer; 11- power transducer; 12- start/stop key; 13- speed/power key; 14-synchrotact; T- Kaplan turbine; G- synchronous generator

The fast evolution of industrial process computers and the major progress achieved in the field of electrohydraulic servovalves have led to widespread use of electrohydraulic equipment in new and refurbished speed and power governors for power plants. These solutions combine excellent static and dynamic performances of hydraulic actuators with the flexibility and reliability of numerical control systems.

Any digital automated speed governor is built for the following operation regimes: a) Unit startup and bringing the generator to synchronous frequency; b) Operation with generator connected to the power network; c) Shutdown in case of damage (sudden unload).

During unit startup, the turbine speed needs to be brought from zero to the synchronous speed in a limited time. This period is specified by internal regulation and represents an important technical characteristics of the hydropower unit. In order to achieve this condition, a turbine startup procedure has been developed: the turbine is first accelerated to a speed close to the synchronous one, and in the next phase the turbine speed is adjusted around the synchronous speed. In order to accelerate the turbine, the wicked gates needs to be quickly opened to about 20% of nominal opening and no further control precision is needed. This requires a large flow of oil for wicket gates and runner blades servomotors. Consequently, the servovalves need to be large opened for about 20 s. Close to the synchronous speed, the accuracy of the speed governor needs to be around 5 ... 10 mHz. Consequently, the flow gain of the valve needs to have different values for the two phases, because the proportional gain of the electronic compensator is kept constant. Software change of the proportional gain of the electronic compensator is less certain than the change the flow gain of the servovalve by shaping the metering ports.

During the operation of the generator connected to the power network the hydropower unit needs to mantain a constant speed and to follow the power reference transmitted by the local or process operator console.

During an insulated operation of the hydropower unit, the speed governor rejects the load variations, keeping the frequency constant. If these disturbances are small (10...20 mHz) the valve operates in the small flow gain area. For large speed disturbances (100...200 mHz) the valve operates in the large flow gain area. In the case of network unit operation, the static droop of the speed governor allows the overall load disturbance. Also, changing the value of the power reference implies changing the wicket gate opening with a speed imposed by specific rules of the electric power systems. In this situation, for small frequency variations, the valve operates in the area where the flow gain has the minimum value. In case of damage (sudden unload) the wicked gate needs to be closed with a speed specific to the hydropower unit type. As closing time is about 6s...10s, the flow needed by the servomotors is very large, and the valve operates in the maximum flow gain area. The electrohydraulic interface consists of two electrohydraulic amplifiers, one for controlling the wicket gate servomotors, and one for controlling the runner blades servomotor. Two servomotors are used for moving the ring that controls the position of the wicket gate blades, and one for adjusting the runner blades.

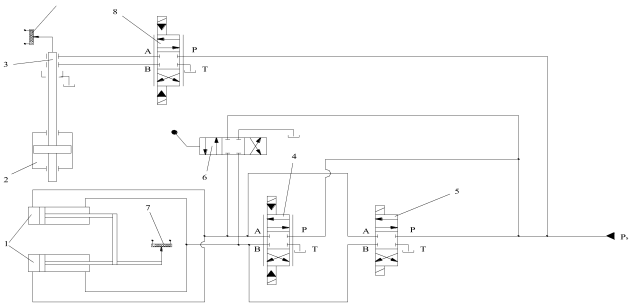


Figure 3: Hydraulic schematic diagram of a speed governor unsing high power electrohydraulic amplifiers: 1 – wicket gate servomotors (S_{AD}); 2 – runner blades servomotor (S_{PR}); 3 – distribution head; 4 – high power proportional valve; 5 – emergency valve; 6 – manually operated tunining valve; 7 – position transducer for S_{AD} rod; 8 – high power electro-hydraulic amplifier (proportional valve); 9 – position transducer for the distribution column, P, T, A, B – hydraulic connections, P_S – supply pressure.

REDUNDANCY OF ELECTROHYDRAULIC SERVOMECHANISMS FOR SPEED GOVERNORS

The principle scheme of a redundant digital servomechanism is presented in fig. 4. In order to test this original concept the autors have developed a system based on co-simulation between LabVIEW and AMESIM (Lebrun et al. 2009).
The electrohydraulic and mechanical components of the servomechanism are simulated in AMESIM, and the process control part, made up of two parallel governors is built in LABVIEW (Cioranu 2012).

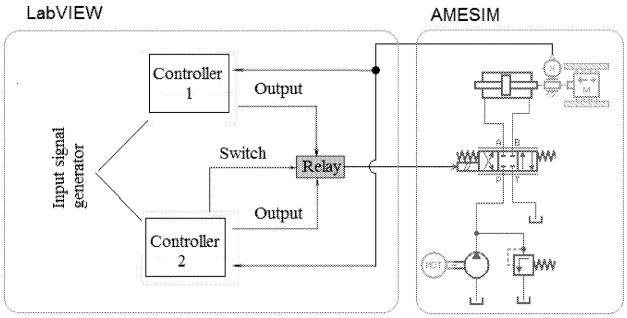


Fig. 4. The principle scheme of a redundant electrohydraulic servosystem

The redundancy core of a servosystem includes two numerical computing units (controler 1 and controler 2) excited by a analog universal signal generator (Standford). After numerical processing of the error signal, obtained by comparing the input signal with the signal corresponding to the physical action of the electrohydraulic system (the position of the rod of the hydraulic servomotor) commands the servovalve. The error signal is analyzed by a PID compensator and the input signal for the electrohydraulic amplifier is received from the active controller via a relay switch.
The relay has a default position in which, without any command signal from controller 2, connects the output of controller 1 to the command input of the valve. Controller 2 can force the switch of the valve command signal by sending a signal to the relay, case in which the output of controller 2 is connected to the command input of the servovalve. The proposed scheme has the advantage that it can be tested on dedicated process control equipment like the NI PXI industrial computers (fig. 5).

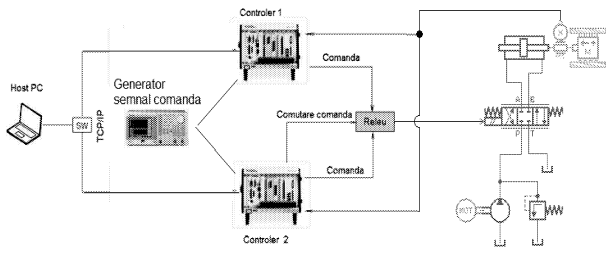


Figure 5: Schematic diagram of a HIL test bench for redundant servomechanisms

Even in the co-simulation procedure the analyzed system can be ported to the respective hardware equipment. The co-simulation procedure has no real time simulation facilities, but it's frequently utilized as a transition step between classical numerical simulation networks and real time simulation ones. This step is usually necessary in order to increase the effectiveness of specific procedures for building real time simulation networs, based on rational simplifications to the classical simulation netoworks.

NONLINEAR MATHEMATICAL MODELLING OF THE ELECTROHYDRAULIC CONTROL SYSTEM

The main equations of the mathematical model of a nonlinear high-speed electrohydraulic speed includes the following equations (Vasiliu D, 1997):
a) Servovalve nonlinear steady-state characteristics,

$$Q_{SV}(x,p) = c_d A(x)\sqrt{\frac{p_s - sign(x)\cdot P}{\rho}}$$

b) Servovalve spool second order transfer function,

$$\frac{x(s)}{U(s)} = \frac{K_{xU}}{\left(\frac{s}{\omega_n}\right)^2 + \frac{2\zeta s}{\omega_n} + 1}$$

c) Position transducer equation,

$$U_T = K_T y$$

d) Continuity equation for the servovalve-cylinder subsystem

$$Q_{SV} = A_p\dot{y} + K_l P + \frac{A_p^2}{R_h}\dot{P}$$

e) Piston motion equation

$$m_c\ddot{y} = F_p - F_a - F_e - F_f$$

The AMESIM simulation network for the electrohydraulic control system is presented in figure 6, and a typical simulation results is presented in figure 7.

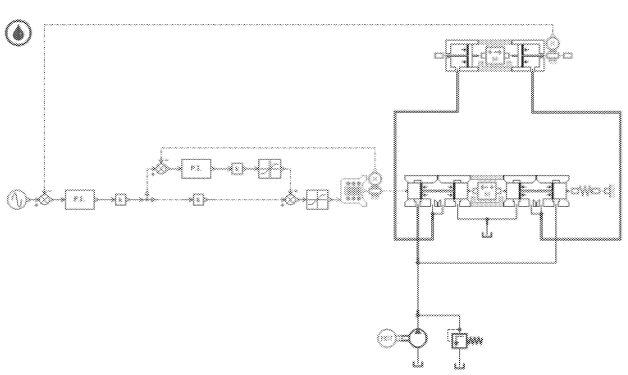


Figure 6: AMESIM simulation network of a nonlinear electrohydraulic servomechanism

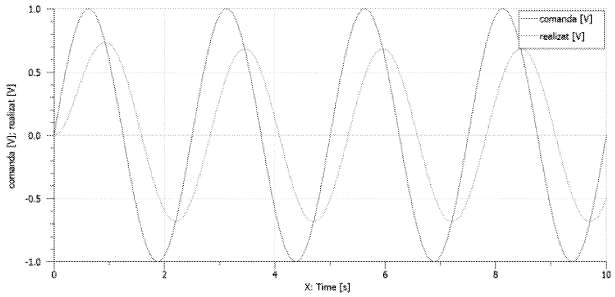


Figure 7: System response to a 0.4Hz sine wave input signal

NUMERICAL SIMULATION OF THE CONTROL SYSTEM INCLUDING REDUNDANCY

For the numerical simulation of the control system including redundancy the authors developed the simulation network from figure 8.

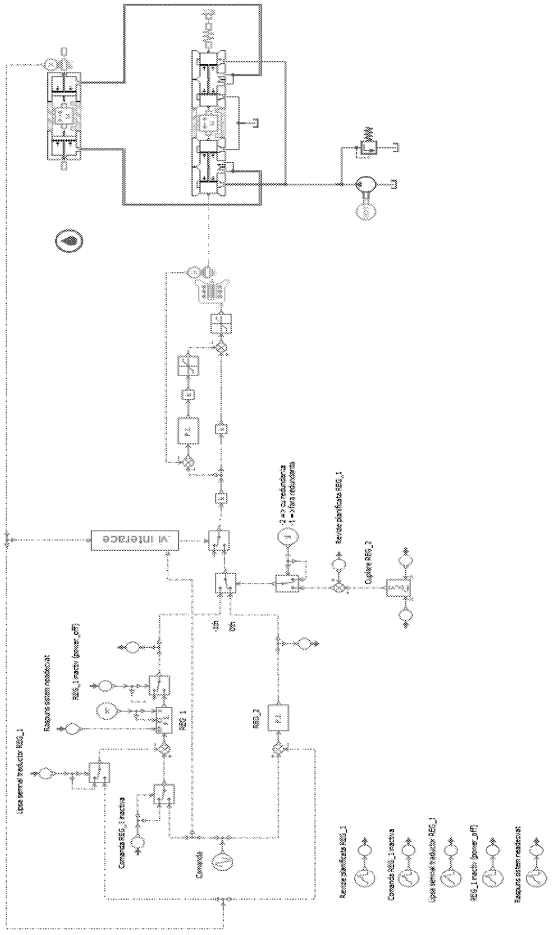


Figure 8: Simulation network of the position control system including redundancy

This network contains the servovalve model, the hydraulic cylinder model, and a decision model composed of two parrallel P.I. controllers and a switching element actuated by the difference between the output signals of the two compensators. The switching element has a reference position (without any command signal it links controller 1 to the servovalve) and when the error computed as the differences between the outputs of the two controller exceeds a preset limit it switches te servovalve control input to controller 2.

In order to simulate malfunctions of controller 1 the simulation network includes a series of switches that, when receiving specific command signals allow coupling or decoupling of the command signal, the linear hydraulic motor position transducer signal, the controller output, the K_p parameter of the controller, and activating a signal that signifies taking controller 1 off-line for scheduled maintenance. These switches have been activated / deactivated at preset time intervals to show the ability of controller 2 and the switching circuit to overcome various malfunctions of controller 1.

Figure 9 shows the activation times of the redundancy trigger conditions.

At t1=5s scheduled maintenance of controller 1 occurs, at t2=12s lack of transducer singal error occurs, at t3=20s no output from controller 1 switch is activated, at t4=25s controller 1 inactive error occurs and at t5=34s a sudden change in the Kp parameter of controller 1 is being made in order to simulate wrong operation.

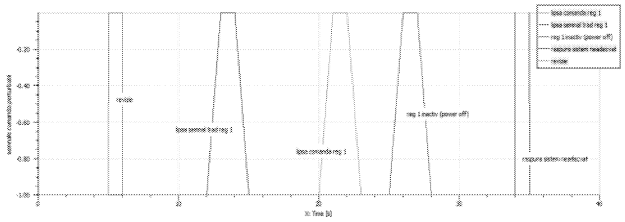


Figure 9: Activation times of the redundancy trigger conditions

Figures 10, 11 and 12 show the response of the system to a sine wave command signal with the redundancy subsystem active, and the response of the system to the same command signal with the redundacy subsystem inactive.

The adequate functioning of the redundacny switching system can be easily noticed (blue signal from figure 10).

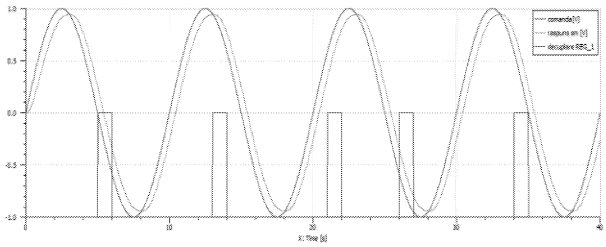


Figure 10: System response to a sine wave input signal with an active redundancy subsystem

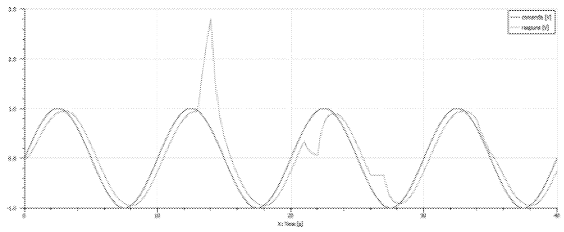


Figure 11: System response to a sine wave input signal with the redundancy subsystem inactive

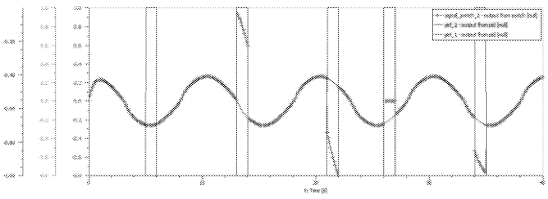


Figure 12: Output of the two compensators, REG_1 and REG_2

IMPLEMENTING REDUNDANCY SOLUTIONS IN HYDROPWER UNIT SPEED GOVERNORS

The final goal of this research has been the developement of a system that includes both hardware and software redundancy (figure 13) for the control of electrohydraulic servomenchanisms similar to those used in hydropwer unit governors. In order to achieve this goal, the authors have designed a dynamic test stand for testing this kind of equipment and a control system consisting of two NI PXI industrial computers. The software solutions loaded on them is simular to the one validated by the simulations presented above. The electrohydraulic control system with redundancy is used in practice for controlling the wicket gate opening of any hydraulic turbine.



Figure 13: Front view of the test bench including the electrohydraulic hardware and the control equipments

MATHEMATICAL MODELLING OF A HIGH HEAD HYDROPOWER FRANCIS UNIT

The study of the stability of systems including a high head Francis turbine is usually done considering the following simplifying considerents (Kundur 1994):
- hydraulic resistance is negligible;
- the penstock is rigid and the water is not compressible;
- water speed through the conduit is proportional to the wicket gate opening and the square root of net head;
- turbine power is proportional with the product of head and flow .

The behaviour of the system consisting of the turbine and the forced conduit depends on:
- water speed in the conduit;
- mechanical power of the turbine;
- water column acceleration.

Water speed in the conduit is given by the equation:

$$Q = K_u X\sqrt{H}$$

where:
Q - flow through the conduit;
X - wicket gate position;
H - head at the wicket gate;
K_u - constant.

For small variation around an operating point,

$$\Delta Q = \frac{\partial Q}{\partial H}\Delta H + \frac{\partial Q}{\partial X}\Delta X$$

which can be written as

$$\frac{\Delta Q}{Q_0} = \frac{\Delta H}{2H_0} + \frac{\Delta X}{X_0}$$

where

$$Q_0 = K_u X_0\sqrt{H_0}$$

or normalized

$$\Delta\bar{Q} = \frac{1}{2}\Delta\bar{H} + \Delta\bar{X}$$

The mechanical power of the turbine is:

$$P_m = K_p Q H$$

For small variations of the power the above becomes

$$\frac{\Delta P_m}{P_{m0}} = \frac{\Delta Q}{Q_0} + \frac{\Delta H}{H_0}$$

where

$$P_{m0} = K_p Q_0 H_0$$

or

$$\Delta\overline{P_m} = \Delta\bar{Q} + \Delta\bar{H}$$

Replacing $\Delta\bar{Q}$ and $\Delta\bar{H}$ we get:

$$\Delta\overline{P_m} = \Delta\bar{X} + 1.5\Delta\bar{H}$$

$$\Delta\overline{P_m} = 3\Delta\bar{Q} - 2\Delta\bar{X}$$

The water column acceleration can be expressed as:

$$(\rho LA)\frac{d\Delta Q}{Adt} = -A \cdot (\rho g \Delta H)$$

where

L = length of the conduit;
A = conduit section area;
ρ = water density;
g = gravitational pull;
ρLA = mass of water in the conduit ;
$\rho g \Delta H$ = pressure variation at the wicket gate. We get

$$\frac{LQ_0}{gAH_0}\frac{d}{dt}\left(\frac{\Delta Q}{Q_0}\right) = -\frac{\Delta H}{H_0}$$

or

$$T_w\frac{d\Delta\bar{Q}}{dt} = -\Delta\bar{H}$$

where

$$T_w = \frac{LQ_0}{gAH_0}$$

Here T_w represents the starting time constant of water and indicates the time needed to achieve flow Q_0 at a head of H_0 by the water column. The relationship between variation in flow and variation in wicket gate opening is:

$$T_w\frac{d\Delta\bar{Q}}{dt} = 2(\Delta\bar{X} - \Delta\bar{Q})$$

Applying the Laplace transform we get

$$T_w \cdot s \cdot \Delta Q(s) = 2\left(\Delta\bar{X}(s) - \Delta\bar{Q}(s)\right)$$

or

$$\Delta\bar{Q}(s) = \frac{1}{1 + 0.5T_w s}\Delta\bar{X}$$

which represents the transfer function for the ideal turbine model:

$$G(s) = \frac{\Delta\overline{P_m}(s)}{\Delta\bar{X}(s)} = \frac{1 - T_w s}{1 + 0.5T_w s}$$

The motion equation for the hydropower unit is:

$$M_a = M_T - M_G$$
$$J\frac{d\omega}{dt} = M_T - M_G$$

The torque of the turbine depends on the flow Q, head H, and speed ω:

$$M_T = M_T(Q, H, \omega)$$

The flow passing through the turbine depends on the wicket gate opening X, head H and speed ω:

$$Q = Q(X, H, \omega)$$

Considering the above, the turbine torque is

$$M_T = M_T(X, H, \omega)$$

The resisant torque of the electric generator depends on electrical impedance Z, generator voltage U and speed ω

$$M_G = M_G(Z, U, \omega)$$

If generator voltage is constant then

$$M_G = M_G(Z, \omega)$$

For small disturbances we can write the following equations:

$$\Delta M_T = \frac{\partial M_T}{\partial X}\Delta X + \frac{\partial M_T}{\partial H}\Delta H + \frac{\partial M_T}{\partial \omega}\Delta\omega$$

$$\Delta M_G = \frac{\partial M_G}{\partial Z}\Delta Z + \frac{\partial M_G}{\partial \omega}\Delta\omega$$

$$J\frac{d(\Delta\omega)}{dt} = \Delta M_T - \Delta M_G$$

The generator power is

$$P_e = M_G\omega$$

Under nominal conditions, the system operates at maximum torque and we can write

$$M_{Tn} = M_{Gn} = M_n$$

A more realisitc approximation of the model can be obtained considering disturbance

$$\Delta\bar{Q} = a_{11}\Delta\bar{H} + a_{12}\Delta\bar{\omega} + a_{13}\Delta\bar{X}$$
$$\Delta\overline{P_m} = a_{21}\Delta\bar{H} + a_{22}\Delta\bar{\omega} + a_{23}\Delta\bar{X}$$

If the hydropower unit is coupled to the power grid, speed variations $\Delta\omega$ are negligible, and the equations become

$$\Delta\bar{Q} = a_{11}\Delta\bar{H} + a_{13}\Delta\bar{X}$$
$$\Delta\overline{P_m} = a_{21}\Delta\bar{H} + a_{23}\Delta\bar{X}$$

HIL SIMULATION OF THE REDUNDANT ELECTROHYDRAULIC CONTROL SYSTEMS

Electrohydraulic control systems are complex systems, involving both phenomena regarding fluid flow in volumic hydraulic transmissions as well as phenomena specific to

control theory. Due to the complexity of these systems, estabilishing the optimal design solutions is done using an iterative process. Achieving the requested performance involves using mathematical modelling and numerical simulation techniques.

In order to determine the constructive parameters of these components, the differential equation systems that describe their dynamic behaviour needs to be solved. These systems are usually non-linear and solving them is usually done using numerical methods. The difference between the real and simulated behaviour of these systems means that an accurate assesment of their functional parameters requires several iterations.

At present, in order to increase the accuracy of mathematical models, hybrid closed-loop simulation is preferred. This type of simulation requires real-time running of the mathematical model, so it can run together with the hardware components of the simulation platform.

In the field of electrohydraulic control systems, closed loop simulations allow real-time validation and tuning of control algorythms. The possibility of using both real-time models as well as real equipment allows tests that would be impossible *on-site* to be done in the research lab.

For doing RT simulation a variety of tools can be used, like: Real Time Windows or xPC Target developed by Mathworks, AMESIM RT developed by IMAGINE France, LabView Real Time – National Instruments etc.

The offer in the field of RT is consistent, offering solutins specific to RT lab simulation as well as industrial solutions. For the redundant system from figure 14, two identical PXI industrial computers running the control algorythm in parallel and one PXI industrial computer to provide real time simulation of the hydro-mechanical components have been used. These machines can communicate with each other using the TCP/IP protocol.

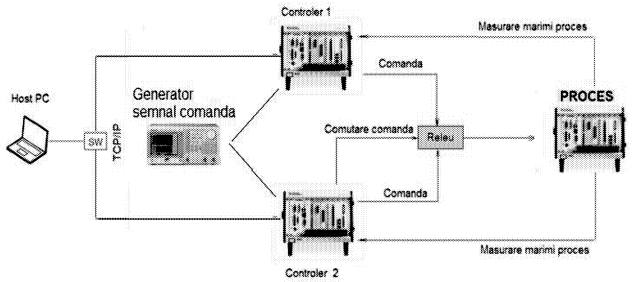


Figure 14: Scheme of the RT simulation system

Both machines are connected to the test stand and can control the process completely. In order to visualize the information at operator level, a separate "host-PC" has been used. The controller implemented on each PXI can control the whole process and can communicate with its ‚sister' machine. Also, it can run a self-diagnostic routine in case it goes out of the process, yelding the control to the other machine. This routine allows the identification of the type of malfunction (if the transducers used allow it or the maximum time allwoed for running specific subroutines is excluded) and, if the problem is identified as software, the machine reinitializes itself (hardware restart). The time evolutions of the main process parameters are presented in fig. 15, 16, 17 and 18 for a square wave input signal. As it can be seen, the redundant system manages to compensate for errors in the primary controller and keep the system's response close to the input signal.

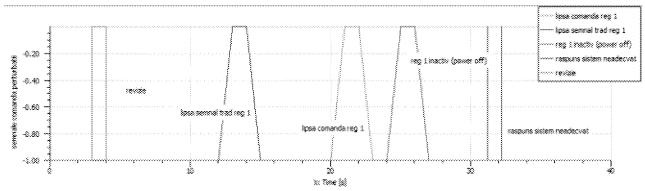


Figure 15: Disturbance signals

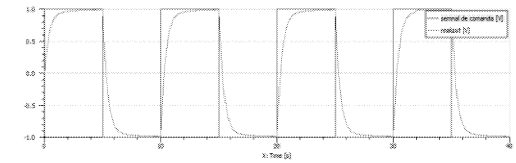


Figure 16: Redundant system response for a series of square inputs

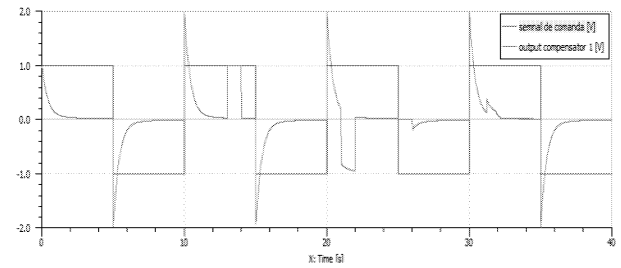


Figure 17: Controller 1 response

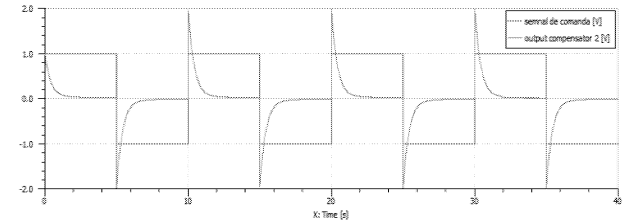


Figure18: Controller 2 response

CONCLUSIONS

The proposed procedure was used with good results by the authors both in the field of low head Kaplan turbine for Ramnicu Valcea Hydropower Plant (Vasiliu and Calinoiu 2003, Vasiliu et al. 2011), and in the field of high head Francis turbine from Raul Mare Retezat Hydropower Plant (Vasiliu and Calinoiu 2012).

The same procedure was completely validated through researches carried out in different type fluid control systems (Muraru et al. 2000; Dragne 2010; Bataus 2011; Popescu et al. 2011; Vasiliu C. 2011; Negoita 2011; Vasiliu et al. 2012; Mitroi 2013).

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The main important contribution came from LMS INTERNATIONAL CORPORATION (Belgium), a permanent partner of the above laboratory.

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LATE PAPER

SMART TEACHING TECHNOLOGIES USED IN A HYBRID LEARNING COURSE MODEL

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KEYWORDS

Smart teaching technology, experiential learning, hybrid learning model, lecture capturing, e-tutor, mathematics

ABSTRACT

Blended Learning is now in evolution, by providing the best mix of face-to-face learning and e-learning activities, in which learners are actively engaged in a competency and constructivism based learning process.
A special focus is on integrating experiential learning activities in the course. Practical exercises and experiments and problem-solving are organized as face to face sessions often in special lab rooms or even outside the classroom and on site of a project partner.
A mix or blend of e-learning (self-study), experiential classroom activities and virtual class activities is the most flexible and social hybrid learning model. It guarantees an effective learning process, in collaboration with peers, the teaching team and external experts.
Smart teaching technologies do exist to develop this kind of hybrid learning course.
Lecture capturing is increasingly in demand as a method of developing online lectures. Lecture capturing means making a digital copy of the lecture and publish it as an online video.
Life lecture capturing is creating videos of the life lectures and lab developed lecture capturing is creating videos in a lab of a simulation of the lecture.
In a course mathematics of Hasselt University, a hybrid learning model has been defined. To support learners an e-tutor is developed based on the lab lecture capturing technology. Students evaluated that e-tutor.

EVOLUTION OF BLENDED LEARNING MODEL

(Schreurs 2012), (Schreurs 2014) The advantage of e-learning is flexible learning being anytime and anywhere.
Some disadvantages of e-learning do exist. e-learning results in low motivation to complete courses, lower learner satisfaction, lack interaction with teachers and peers, difficult to use real tools, and high initial costs for developing courses.
Blended Learning arose to overcome the disadvantages of traditional learning and to obviate the failure of e-learning. A blended or hybrid learning model is mixing face-to-face and e-learning activities in the learning process. (Schreurs 2012) The learning process consists of event-based learning activities, including face-to-face class room, live e-learning, and self-paced learning, which increases learning quality, social context, and learners' interactivity.

A criticisms on the first generation of Blended Learning is that it focuses on the teacher for creating knowledge, rather than on the learner. Failure to use effective learning theories in designing and implementing learning activities, affects negatively on the learning quality and outcomes. Technology alone tends to focus on presenting learning contents rather than on insuring the engagement of learners and the effectiveness of the learning process.
Blended Learning is now in evolution. Blended learning will now also integrate the concept of competency based and constructivism based learning. (Schreurs 2012) (Koohang 2009) The development of the learning process starts from the pre-decided set of learning outcomes taking into account the pre-defined competences and the opportunities of learning technology. A special focus is on integrating experiences in the course. Practical exercises and experiments and problem-solving are organized as face to face sessions often in special lab rooms or even outside the classroom and on site of a project partner.

Teachers should select the right technology and learning method for the right learning activity and for the right learner. The e-learning modules are part of the blended learning process.

BLENDING E_LEARNING WITH EXPERIENTIAL LEARNING

If the "face to face" classroom teaching sessions are limited in time and if part of the theoretical sessions are replaced by e-learning course modules, than classroom time can be freed for more active and learner centred learning activities. These consists of research activities, problem solving, project work (based on the concept of constructivism and connectionism concept that is set forward. Learning can evolve to experiential learning.(Kayes 2002) In experiential learning the learning activities will be planned in which the learners will be active and will participate in relevant experiments and in problem solving of a lab case or even of a real business problem. In this project based learning model, the learners will be members of a project team in co-operation with peers and also wit professional experts.

FLIPPED CLASSROOM

(Schreurs 2013) In the traditional educational model learners are required to listen to a lecture in class and then complete homework afterwards. In a flipped class model, the traditional in class activities (like lecture) are moved to homework time, and traditional homework activities are moved to the class meeting time. (Alvarez 2011). It means that the traditional face to face introduction in the theory will (partly) be replaced by online self-instruction, facilitated by e-learning course modules. Active learning activities are organised during classroom time.
The flipped model is more effective. Educational psychologists have understood for decades that people generally learn better through interactive conversation, engagement and opportunities to explore, practice and reflect.

Online video lectures in the flipped class

(Franciszkowicz 2008)
Many universities are experimenting with changing from in-class lectures to video lectures. Lectures were captured life or in lab. The video lectures were posted on their Learning management system (LMS), on private intranet or even on You Tube, giving students convenient, anytime access.

Activities in class

Universities are using class time to support students in class, to explore the challenging and more difficult aspects of course content, by revisiting concepts students don't understand. Faculty can devote time to help students develop synthesis and explore applications during class time through: experiential exercises, team projects, problem sets, doing labs or interactive activities.

ADDING VIRTUAL CLASSROOM TO THE LEARNING MIX.

(Schreurs 2013) Using the classroom to communicate complex processes to large groups has historically been difficult to achieve efficiently and without devoting significant resources. This deficiency can be fulfilled to some extent by introducing live or virtual classroom.
As organisations become more sophisticated in their use of learning technologies, they can offer online learning solutions. The entire learning process does not have to run in real time. The self-paced (asynchronous) e-learning can be blended with the life classes (synchronous) together to make an advanced virtual classroom. Ways of incorporating virtual classroom/ life e-learning experience are : chat sessions, discussions, threads, group works, and real-time class meetings with whiteboard and file-sharing.
Learners are brought together in open learning environments. Students are using blogs, wikis, second life, and are meeting in social community groups (Facebook). This blended model is a favoured one for professional learners.

A HYBRID LEARNING COURSE MODEL

(Schreurs 2013) Creating an optimal blend, being a sound mix of e-learning, face-to-face experiential learning and a virtual class is our challenge. In the table we see an overview of learning activities belonging to each of the three types of learning.

e-learning	**Classroom**
intro in the learning content additional information assignments as part of learning process testing	Discussions about topic, problems and solutions and deeper learning of the topic Experiences (practice, projects), sharing them with peers, experts and reflect on them
Virtual classroom Tutoring in self-study, discussion with peers about it, virtual meeting, team reporting on distance	

Table 1: a sound mix of e-learning, classroom and virtual classroom. (4)

A mix or blend of e-learning (self-study), experiential classroom activities and virtual class activities is the most flexible and social hybrid model for the learner. It guarantees an effective learning process, in collaboration with peers and teaching team and external experts and expertise and prepares the learners best for their future professional functioning.
Smart teaching technologies do exist to develop this hybrid learning course

SMART TEACHING TECHNOLOGIES TO DEVELOP ONLINE LEARNING COURSE AND ACTIVITIES (Schreurs2013)

Lecture capturing

Lecture capturing means making a digital copy of the lecture and publish it as an online video.
Lecture capturing is increasingly in demand as a method of developing online lectures. Life lecture capturing is creating videos of the life lectures and lab developed lecture capturing is creating videos in a lab of a simulation of the lecture. (Kreski 2012)

Life lecture capturing

Following are 3 types of life lecture capturing methods to create online lectures:
Life video lecture capturing during the face to face session. A digital copy or a video recording of the lecture is made. This video is made available online for the learners. Oregon State University has implemented lecture capturing as a solution on institutional level. (Tsai)
Capturing life video by combining the input with input from using a digital interactive whiteboard (Smartboard) in connection with a PC, a projector and white-boarding SW. The whiteboard accepts PC output (prepared in advance) and finger and pen writing on the whiteboard (during the session). The end presentation file combining all the info will be available after class. Missouri State university is a good example:

(http://www.youtube.com/education?category=University/Mathematics)
KBC, Belgian Bank and Insurances company, has implemented the concept as a method of e-learning development.
Screen-casting of PC screen output (prepared in advance) and handwritten pen input on Wacom display (during the session) and screen capturing SW, results in a life presentation.
Hasselt University is capturing computer screen output created by combining in advance prepared presentation in PFD format with life handwriting annotations on a Wacom display (http://www.wacom.com/en/business-and-education/products/pen-displays) added as annotations during the session. After class the presentation can be available as a file or can be available as an online web video presentation

Lab developed lecture capturing
Even more valuable is the concept of "lab lecture capturing". It means computer screen capturing of a combination of prepared content (pictures, PPT slides, …) with handwritten content and voice input , all created on a computer whiteboard and in a screen capturing software environment. The simulated lecture is published as a flash-file or as a video-file and made available on the web.
An online simulation/ presentation of a life lecture can be prepared offline using screen capture software and hand-writing facility on a Wacom display or another tablet.

Following are case examples of application of ***Lab developed lecture capturing*** to develop online courses
Missouri State university:
http://www.youtube.com/watch?v=kQCy0U0Zjg4
Life lectures have been captured in an advanced technological environment and we can see computer input and handwriting facility and voice input are mixed.
KHAN Academy:
http://www.khanacademy.org/math/differential-equations/first-order-differential-equations/differential-equations-intro/v/what-is-a-differential-equation
This is the most famous lab developed lecture capturing example. Khan produced thousands of math modules and made them free accessible worldwide. Presentation of the intro in the topic is presented in an attractive blackboard simulation.
NROC: http://nroc.remote-learner.net/course/view.php?id=181
Producing and making available lab developed lecture captures of mathematical concepts is an initiative of NROC : http://nrocmath.org/
The videos are part of their tutoring math system.
COURSERA:
https://www.coursera.org/course/mathematicalmethods
It is another example of lab lecture capturing where the handwritten text input is replaced by typed one. Characteristic in their approach is the inclusion of the instructor in the video.
Coursera is services organization cooperating with Us universities in developing their online video courses.

SMART TEACHING TECHNOLOGIES USED IN THE HYBRID LEARNING COURSE MODEL IN THE COURSE MATHEMATICS (Melis 2004), (Stevenson 2011), (Epper 2009), (Tsai), (Carey)

Problem: incoming students are not ready for course mathematics
First year students in applied economic sciences experience problems with the course mathematics. Some incoming students are not ready to start the course math. They have to be motivated to enhance their mathematics knowledge level before the start of the academic year. All those candidate students can now test themselves and can participate in a face-to-face organized preparatory course to improve their math knowledge level.
But even if students have done this remedial activity, many of them still have a lot of problems in the first year course mathematics for business economics. Those students have a different mathematical attitude, and as a consequence need a different guidance. Some students need additional help to succeed in math. We need to offer them the instruction they need. We decided to develop an e-tutor , presenting online simulation of the classroom sessions and the possibility of guidance in solving mathematical exercises

Hybrid learning model
The following hybrid course model, composed of 5 components, was developed:

1.(online) individualised **remediation** of pre-requisite math knowledge.
2.A few **face-to-face lectures** introducing the concepts of the theory, and the applications in a business environment
3.a **practice session** in the classroom where students are guided in solving exercises
4.Online lectures and practice sessions to support individual learning
5.online self-study exercises and problems guided by the system

e-tutor learning activities
An e-tutor is developed and the following learning activities included in the e-tutor:

LA1: Presentation Theory: The theory of the chapter is presented as a video, being a sequence of boards, being a simulation of the classroom lecture. The student can access the online lecture or parts of it.
LA2: Presentation example exercises: Students will be shown solving some example exercises
LA3: self-study stepwise solving exercises: Solved exercises are available in a question base. Students can select exercises and they will be trained in solving the exercises in a stepwise way. While a student is solving an exercise he can ask for a next step of the solution, or he can ask for the final outcome
Figure 1, is one page of the presentation of the theory in the e-tutor.
Figure 2 is one page of the stepwise solving exercises.

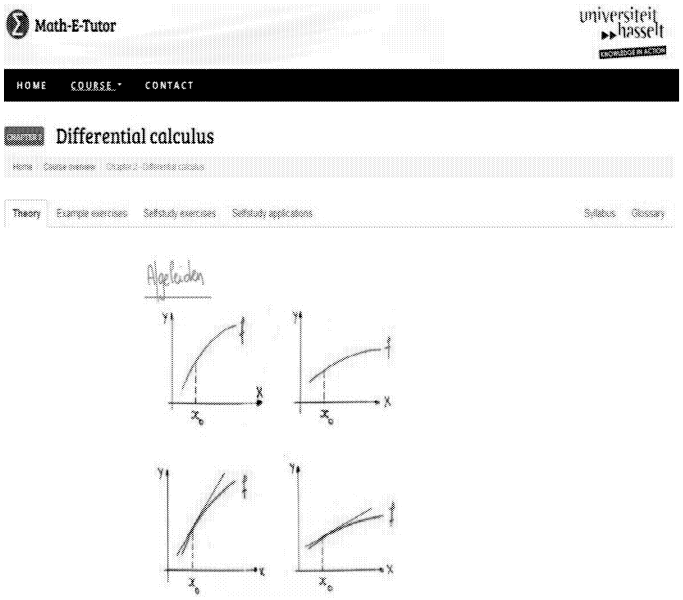


Figure 1: e-tutor: presentation of theory session

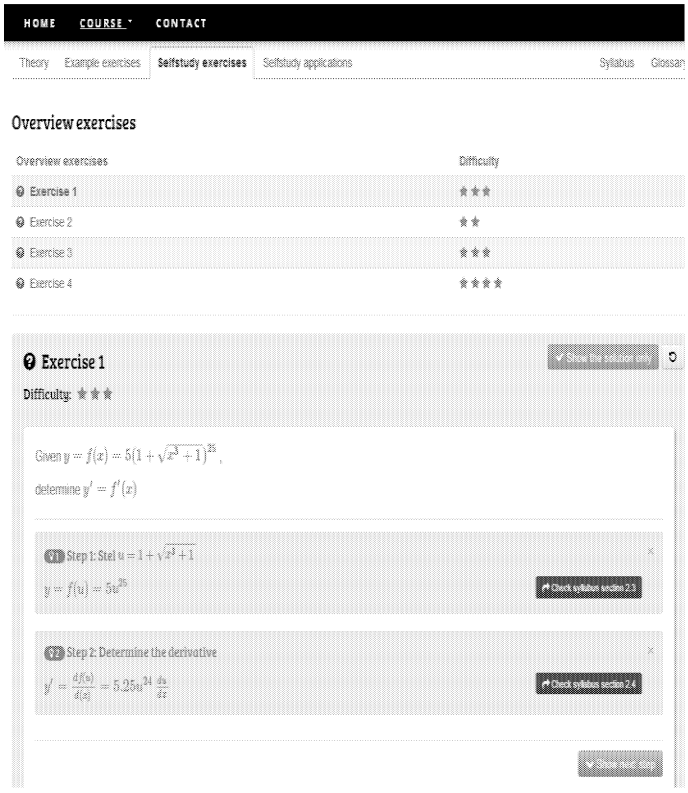


Figure 2: stepwise solving exercises

Technology

The presentation part of the e-tutor is developed as a "lab lecture capturing" application. Attractive visual presentations of the theoretical modules are focusing on the concepts, the exercises and applications in business context. Lab lecture presentations of the face-to-face lectures are developed using the software Lecturescribe (Clemson University) (or Camtasia). Spoken explanations and handwritten input on a Wacom display are integrated and published as a flash file.

Lab lecture development infrastructure:

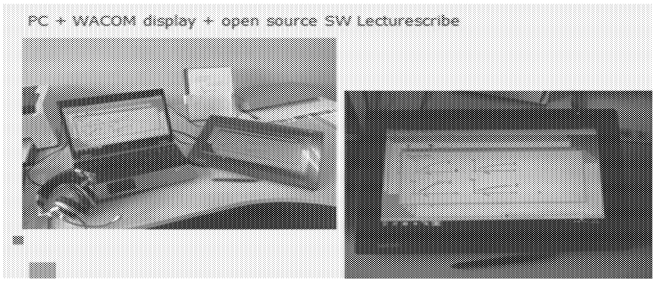


Figure 3: It infrastructure

The lab infrastructure is composed of a multimedia desktop and a Wacom display with pen. LecureScribe is the open source software to develop the flash file.

IMPLEMENTATION AND EVALUATION

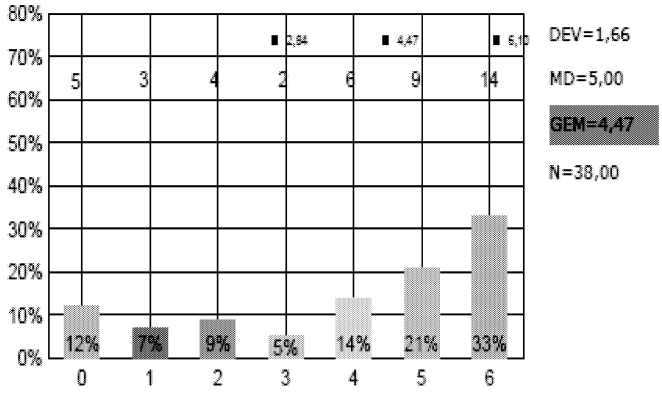
Math-e-tutor is implemented in the course mathematics this academic year.
The e-tutor is a success. Students are using it very active as measured via statistics :

Number of exercises	84
Number of students using the system	91
Total number of exercises opened	5220
Mean number per student	57,36
Most popular exercise	2.01:142 times opened

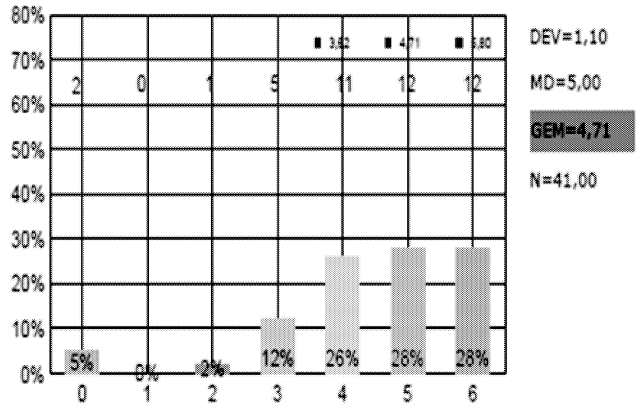
Table 2 : statistics of e-tutor use

Evaluation by students
At the end of the semester, as part of the course evaluation ; 4 questions are included to evaluate the e-tutor. The answers are:
1: disagree
2: not agree
3:rather not agree
4:rather agree
5: agree
6:fully agree

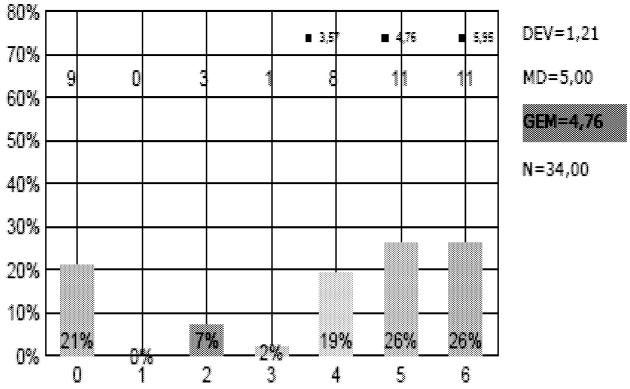
Question 1 : I am using the e-tutor regularly



Question 2 : The online presentation of the theory was supporting my learning



Question 3 : The online exercise-examples were supporting my learning.



Question 4 The self-instruction exercises supported my learning

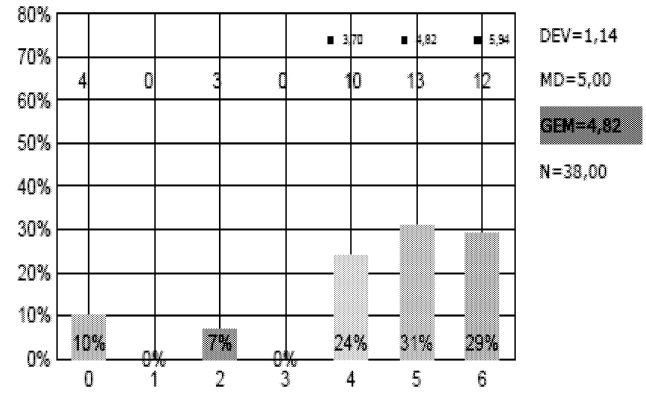


Figure 4: evaluation e-tutor by students

Overview of 4 questions:

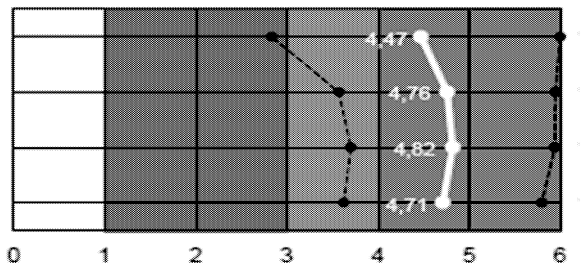


Figure 5: overview of evaluation

FUTURE OPPORTUNITIES

The quality of the online lectures is high and can replace the face-to-face lectures.
Discussion: why not moving some learning content to the online environment, thus freeing face-to-face lecturing time for more problem solving activities in the classroom.
My vision : the flipped class is a model for this course. The students can learn the theory using the online sessions of the e-tutor. The classroom time can be spent in solving exercises. Experiential learning can be developed for the classroom sessions. In their online learning of the theory they need to have the facility to communicate with peers and professors. The needed virtual tools can be installed in function of that individual study

CONCLUSION

A mix or blend of e-learning (self-study), experiential classroom activities and virtual class activities is the most flexible and social hybrid learning model.
Creating an optimal blend, being a sound mix of e-learning, face-to-face experiential learning and a virtual class is our challenge.
The hybrid learning model is a sound mix of e-learning, classroom and virtual classroom learning. Collaboration with peers and teaching team and external experts and expertise prepare the learners best for their future professional functioning.
Smart teaching technologies do exist to develop this hybrid learning course
Lecture capturing means making a digital copy of the lecture and publish it as an online video.
Lecture capturing is increasingly in demand as a method of developing online lectures. Life lecture capturing is creating videos of the life lectures and lab developed lecture capturing is creating videos in a lab of a simulation of the lecture.

"lab lecture capturing" means computer screen capturing of a combination of prepared content (pictures, PPT slides, …) with handwritten content and voice input , all created on a computer whiteboard and in a screen capturing software environment. The simulated lecture is published as a flash-file or as a video-file and made available on the web.

Some case examples of application of ***Lab developed lecture capturing*** to develop online courses are found in the literature. In the course mathematics of Hasselt University, a hybrid learning model has been defined. To support learners, an e-tutor is developed, based on the lab lecture capturing technology. Students evaluated that e-tutor.

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About used technology: The presentation part of the e-tutor is developed as a "lab lecture capturing" application. Attractive visual presentations of the theoretical modules are focusing on the concepts, the exercises and applications in business context. Lab lecture presentations of the face-to-face lectures are developed using the software Lecturescribe (Clemson University) (or Camtasia). Spoken explanations and handwritten input on a Wacom display are integrated and published as a flash file.
The lab infrastructure is composed of a multimedia desktop and a Wacom display with pen. LecureScribe is the open source software to develop the flash file.

Math-e-tutor is implemented in the course mathematics this academic year.
The e-tutor is a success. Students are using it very active as measured via statistics :
As a future vision, we accept that the e-tutor was replacing (part of the) face-to-face lectures.
The quality of the online lectures is high and as a future opportunity replacement of the face-to-face lectures.

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