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An M+I+T++ Research Approach to Network-Based Mobile Education (NBME) and Teaching–Studying–Learning Processes: Towards a Global Metamodel

Ruokamo, Heli; and Tella, Seppo

Abstract—*One of the principal pedagogical insights of recent years has been the recognition of the teaching–studying–learning (TSL) processes, whose three components are equally pivotal and essential to understanding the entirety. A second innovation, which has developed with advances in information and communication technologies (ICTs), is network-based education (NBE). In this paper we argue that (1) it is essential to examine TSL as multi-, inter- and transdisciplinary (M+I+T++) processes and to adopt a future orientation in doing so; that (2) the concept of NBE should be extended to include the added value brought by network-based mobile education (NBME), and that (3) taking these first two orientations into account allows us to create the theoretical prerequisites for better understanding the mechanisms and regularities underpinning knowledge construction in novel operating environments that make use of technology. These arguments constitute the foundation of the global metamodel developed in the MOMENTS project.*

Key words—*information and communication technologies (ICTs), global metamodel, multi-, inter- and transdisciplinary (M+I+T++) research approaches, network-based education (NBE), network-based mobile education (NBME); teaching–studying–learning (TSL) processes*

1. *A Look into the Future of M+I+T++ TSL Processes and Network-Based Mobile Education*

One of the principal pedagogical insights of recent years has been the shift in focus to the teaching–studying–learning process (the TSL process), in which each of the three components is pivotal and essential to understanding the entirety [1]; [2]; [3]. It has also been recognized that speaking of learning alone yields an excessively limited picture of the reality involved. A second innovation that has emerged in tandem with the development of ICTs is network-based education (NBE). By this concept we refer to teaching, studying and learning that is supported by, or in part based on, information and communication networks, in particular materials that can be accessed via or produced on the Internet. Accordingly, NBE combines face-to-face teaching and net-based teaching to form a symbiotic flexi-mode teaching that is more than the sum of its parts [2]. NBE can also be seen as the creation, development and application of a shared public space and set of tools. It supports students and teachers in acquiring information and skills in the focal field of study, in engaging in discussion and exchanging opinions and thereby in making best use of the different views they each bring to the shared studying process. In our view, NBE implements the theory of distributed cognition and expertise, with a view to enhanced collaboration. [4]; [5]; [6]; [7]; [8]

While acknowledging these developments, we would nevertheless contend that it is beneficial, indeed essential, to examine teaching, studying and learning as multi-, inter- and transdisciplinary (M+I+T++) processes, to look at them from the perspective of different academic fields and areas of knowledge, and to do so with a focus squarely on the future. Second, we assert that the concept of network-based education (NBE) must be extended to include the added value which network-based mobile education (NBME) brings to it, that is, mobile technologies and applications. Third, we claim that proper consideration of the previous two points of view will enable us to lay the requisite theoretical foundation for better understanding the principles, practices, mechanisms and regularities underpinning knowledge co-construction or appropriation in novel operating environments that make use of technology, whether the focus of these environments is teaching, studying, learning, work or communication. [9]; [10]; [5]; [6]; [7]; [8]

The foregoing arguments constitute the foundation of the metamodel that has been elaborated in the MOMENTS project. The global metamodel of the MOMENTS project is a M+I+T++ framework that describes the teaching, studying and learning of the future, takes account of individual and communal knowledge co-construction, and accommodates and structures network-based mobile education. The approach includes perspectives of both education and training. One salient function of the global metamodel in the research consortium is to facilitate the M+I+T++ research by providing a consistent system of concepts and terminology across different disciplines. For the academic community at large, the model functions as an empowering mediator in disseminating the consortium's ideas and in collecting feedback. [5]; [6]; [7]; [8]

2. The Metamodel: Conceptual Levels of Observation, Main Components, and Dimensions

The foundation of the MOMENTS integrated metamodel comprises four conceptual levels of observation (figure 1; e.g., [11]). The levels reflect the conceptual parameters that structure our thinking—from cultural discourses and cultural practices to pedagogical models and principles. The level of action in the model embraces conscious as well as subconscious study and the entirety of actions in which individual acts figure prominently. While these acts always take place in particular situations, which give the acts meaning, the users nevertheless conceive of what they do as action rather than as discrete acts. Intersecting the four conceptual levels of observation are the three main components of the model: culture, interaction, and adaptability. These have been chosen with regard to the project's research objectives to represent the broad underlying theoretical issues that will be concretized and brought into focus through the research. [5]; [6]; [7]; [8]

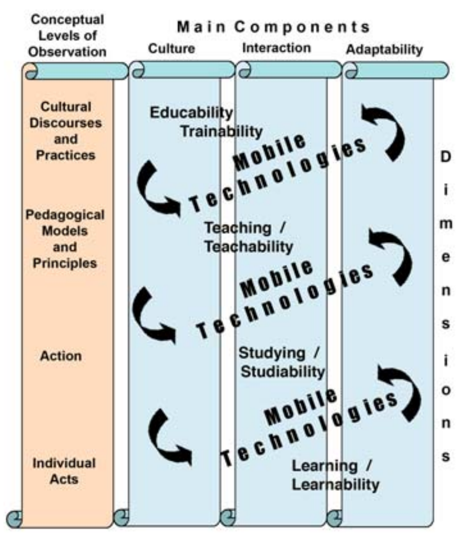

Figure 1. The conceptual levels of observation, the main components and the dimensions of the MOMENTS integrated metamodel.

At the intersection of the conceptual levels of observation and the main components lie the model's dimensions, whose relative prominence depends on the perspective under consideration. The focus of the dimensions is pedagogical activity, which is realized as a didactic teaching–studying–learning process [1]; [2, 19–30]. This process may also be invoked when looking at informal education, training in the workplace, and on-the-job training. As an extension of the didactic teaching–studying–learning process, we investigate teachability, studiability and learnability, which in broad perspective we see as including educability and trainability [12]. The elements of the process are examined with particular emphasis on interventions that make use of mobile technologies (for a detailed treatment, see [2, 19–30]); in other words, we are interested in what takes place when mobile ICTs are applied along the teaching–studying or studying–learning axis. In the MOMENTS project, we pay particular attention to the educational use of ICTs, mobile technologies, virtual and network technologies, and a number of games available (cf. figure 3). [9]; [10]; [5]; [6]; [7]; [8]

In our view, the conceptual levels of observation we have developed and their related perspectives make it possible to organize and conceptualize studies drawing on different background disciplines and fields of research and to locate the new knowledge derived from them appropriately within the cumulative knowledge base of the researchers taking part in the project. New knowledge is created where the conceptual levels, components and dimensions intersect. The theoretical framework provided by the metamodel lends itself precisely to the study of the mechanisms by which individual and communal knowledge are co-constructed. The integrated MOMENTS metamodel encompasses research on teaching, studying and learning from cultural discourses and practices to discrete, automatic acts of teaching and learning in network-based education and study in general, and in network-based mobile education in particular. The latter include the use and adaptability of digital learning materials.

We would like to underline that the perspectives incorporated in the metamodel may be examined in different ways from the standpoint of different scientific disciplines and areas of knowledge and with varying emphases. For example, mobile technology can be connected with game-based activities or playful learning [13]; [14]; [38]; [39] and network technology can enhance media proficiency and encourage use of this proficiency in individuals, groups or communities and contribute to lifelong and lifewide learning, for example. [15]; [6]; [7]; [8]

According to Tella [2, 30], media proficiency refers to a more active and productive command of and ability to communicate using media and new technologies than the traditional media literacy denotes. It is a proficiency that individuals will, optimally, use throughout their lives for self-development. Media proficiency entails ethical and esthetic considerations, as well as a broader understanding than at present of the significance of audio-visual and graphical communication *vis-à-vis* the textual culture that has prevailed to date. Where these areas of learning mentioned above coalesce, media and education meet to form a harmonic whole—media education. The term 'playful learning' for its part embraces the processes of guiding, playing, playing games, learning and growing [13]; [14]; [5]; [6]; [7]; [8]; [38].

The mediated and direct communication made possible by different technologies, means of communication and applications entail unprecedented challenges where culture and interaction are concerned, challenges which education and training must address (on the dimensions of direct and mediated communication, see, e.g., [16, 70]; [17]; see also [18]; [16, 113]). The direct and mediated communication in network-based education and studying can be examined as it occurs between teachers, tutors, students, content designers and technical support staff, as well as between these actors and the technology [19]; [20]; [37]. Here, we must bear in mind that culture and the cultural context more often than not become one of the actors in what is a very diverse communicative forum. In order to better explain the integrated metamodel, we will present each of its different elements in detail. [5]; [6]; [7]; [8]

3. The Didactic Teaching–Studying–Learning Process and the Components Teachability, Studiability, and Learnability

Lying at the center of the dimensions of the MOMENTS metamodel is the *didactic teaching–studying–learning process*. We have elsewhere argued for the importance of all three elements of this process [2, 19–30]; [21]. It is only with an understanding of their mutual interaction and dynamic that we can achieve a sufficiently rich vantage point for examining the mechanisms and regularities underpinning the co-construction of new individual and communal knowledge. In the field of didactics, the preference is to speak of purposive and active learning and support for meaningful learning on the part of the pupil/student rather than of meaningful learning alone, which is a problematic notion in network environments. Studying combines knowledge management and self-directedness, both being directly linked to the individuals' cognitive strategies, i.e., how they select and shape their learning, recall and thinking [22, 24]; [39]. The challenge didactically is how the action of the student—studying—can be organized on a network in a manner that supports and stimulates learning. We have previously framed these three elements—teaching, studying, and learning—in terms of different *descriptors*. (Figure 2: e.g. [21]; [11]; [23], [24]; [5]; [6]; [7]; [8]; [39]; [40])

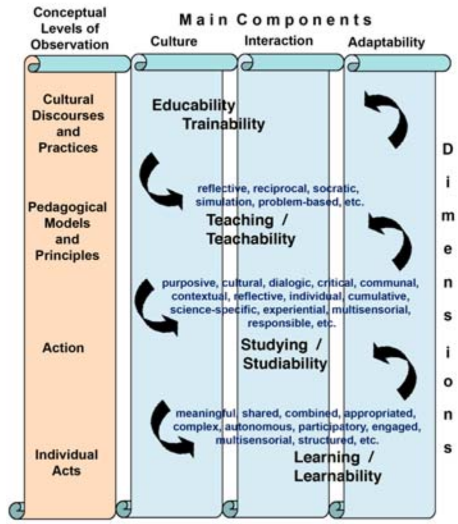

FIGURE 2. Some descriptors of the teaching–studying–learning process.

The descriptors characterizing the three elements of the teaching–studying–learning process are neither mutually exclusive nor exclusive of other descriptors. The process may take on a particular didactic and pedagogical focus in institutional educational settings and related network environments (for a more detailed analysis, see, e.g. [2, 24–29]). In the workplace and adult education, the operating environment may be described in other terms that provide a better account of the focal group. ([5]; [6]; [7]; [8]

We have drawn on the teaching–studying–learning process to derive the components teachability, studiability and learnability (figure 2). The rationale for this approach lies, on the one hand, in its scientific foundation and, on the other, in what is known as the teachability hypothesis. In the context of the MOMENTS project, the hypothesis can be set out as follows:

> A given technical skill (technology, application, structure, etc.) can be learned through teaching only if the learner's (student's, pupil's) basic level of skill and knowledge (intermediate language) and the tools used in the teaching are sufficiently close to the level of skill and knowledge at which and the tools with which the skill in question can be acquired in a natural setting (based on [25, 29] and [26, 201]; cf. Zone of Proximal Development, ZPD, [27] and [28, 35]; see also [16, 32]).

The distinction drawn here between the teaching–studying–learning process and the components teachability, studiability and learnability is a crucial one. Discriminating between the two serves to reduce the vague, albeit fashionable, usage that favors network-based education without further specification. In our view, there is no separate network-based learning: there is only learning which is the outcome of a variety of teaching and study-related measures, an increasing number of which are carried out on information networks. It is our contention that studying is a different matter than learning, regardless of whether studying takes place using ICTs or in face-to-face encounters.

[9]; [10]; [5]; [6]; [7]; [8]

By giving due consideration to the scientific underpinnings of education, in particular media education, we can justifiably speak of educability (figure 1; e.g. [12]). The debate regarding educability is closely linked to that concerning growth, which is one of the prerequisites for lifelong and lifewide studying and learning. These are the focus of the Academy of Finland's *Life as Learning* research program that is the backdrop for the MOMENTS project. In different occupations and in working life generally, educability can be replaced by or considered equivalent to the notion of trainability. The teaching–studying–learning process and the components teachability, studiability and learnability are examined in the latter sections of the article as dimensions similar to the theoretical issues informing the model. We do not overlook the importance of these dimensions although our attention focuses on the other features of the metamodel. [5]; [6]; [7]; [8]

4 Different Forms of Interventions Using Technologies

The central issue in the MOMENTS metamodel is what kind of interventions different techniques and technologies create, enable and effect when they are used in connection with teaching, studying or learning; and how teachability, studiability and learnability are then defined (figure 3; see also [2, 19–30]. The MOMENTS project pays particular attention to mobile technologies but without overlooking the potential of other network or virtual techniques and technologies. [5]; [6]; [7]; [8]

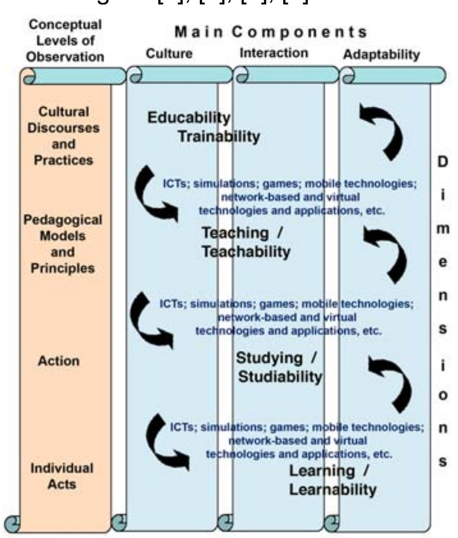

FIGURE 3. Different forms of techniques and technologies producing interventions.

An intervention may take place with the aid or by means of any of the following: ICTs, simulations, games, mobile technologies, and network-based and virtual technologies and applications. In such instances, changes occur in the relationship between training and trainability, education and educability, teaching and teachability, studying and studiability, as well as learning and learnability. Communication changes and the ways in which new knowledge is co-constructed become more complex. [5]; [6]; [7]; [8]

One of the principal underpinnings of the metamodel has to do with mobile technologies and how mobility is reflected in the teaching–studying–learning process, for example, in the form of m-, or mobile, studying. Tella [29] defines mobile studying as follows:

> Generally speaking, [mobile studying] refers to studying and communication, in which different tools of [mobile studying] and mobile technologies are used. As mobile technologies, I regard all different mobile, 'portable' and 'hand-size, pocket-size' multimedia communicators, smart telephones, PDA gadgets and many other that have not yet been launched on the markets. [29, 7]

Tella [22], [29] also introduces a new interpretation, one considered pivotal in the MOMENTS metamodel and related research: an emphasis on the relation between technology and communication as mediation:

> Many link m in a prosaic way to the word 'mobile', which means something that can move, be moved or transported. Mobile associates with movement and mobility and in the same way [mobile studying] implies the opportunity of [studying] elsewhere, in movement, when not immobile or stationary. Mobile answers the question Where? On the other hand, as Sariola et al. (2002) have argued, m can also stand for 'mediated'. Then the question is of mediated studying, in which the mediation process is carried out by technology (cf. CMC = computer-mediated communication; VMC = video-mediated communication). Thus, m can be mobile but also mediated. Mediation answers the question how and mediated by which or by whom. [29, 8, 35]

Lehtonen and Vahtivuori [9] elaborate the definition of mobility, stressing wireless, mediated communication between people:

> In the MOMENTS project, [mobility] is regarded as movability, as mobile tools for activity and thought which have associated with them intense interaction with another or other actors and technological systems or artefacts … Mind tools may function as one approach to understanding mobility and serve in research as part of the teaching–studying–learning process. In this context, mobile tools are seen as a range of tools that support thought and activity and are well suited to a particular situation and activity. These tools … mediate the activity and thinking of their user in a particular situation for a particular teaching- or study-related purpose. [9]; [10]

This analysis of mobility has an important part to play in increasing the understanding of network-based mobile education, as it underlines the relation between mobility, interaction, mind tools and activity. [5]; [6]; [7]; [8]

5. The Main Components of the Integrated Metamodel: Culture, Adaptability and Interaction

The operating environments described in the previous section and the affordances they provide are natural settings for the three main components of the metamodel: *culture, adaptability,* and *interaction* (figure 4). We will take these up in detail in this section.

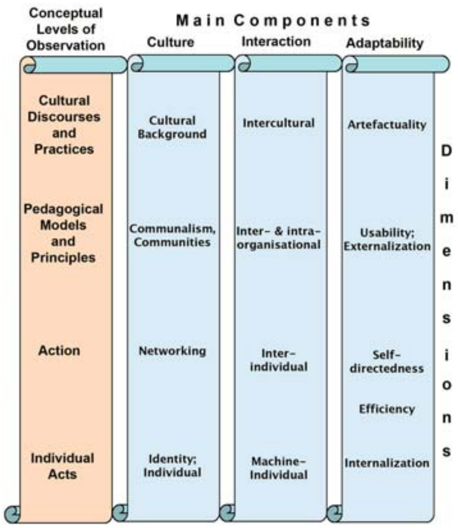

Figure 4. Some key dimensions of culture, interaction and adaptability.

Each of these three main components can be subdivided into parts that are related to the four conceptual levels of observation. They are reflected in different ways where the model's dimensions intersect and, in particular, as the outcomes of different technical interventions. The sub-concepts related to the main components are presented in figure 4.

In the sections that follow (5.1–5.3) we examine each of the components in turn. Section 5.4 takes up the interaction among the three. [5]; [6]; [7]; [8]

5.1 Culture

The central concepts in the culture component are *cultural background, communalism, communities, networking*, and *identity* and the *individual*. We do not treat all of these dimensions of culture in detail here but, rather, provide a summary of our research findings related to culture on the whole. Cultural background intersects the conceptual level of cultural discourses and practices. This background should, however, be understood as a set of expectations and conventions that passes through all levels, components and dimensions of the integrated metamodel. It also influences how individuals, groups and organizations respond to the use of technology as part of the teaching–studying–learning process. For instance, the relative status of mediated and direct communication varies in different cultures. What we see here is the significance of the sociocultural environment in particular for communication at the individual and communal levels. Given the heuristic nature of the integrated metamodel, the inclusion of culture as a level in its own right is justified, though. [5]; [6]; [7]; [8]

5.2 Adaptability

The sub-concepts of adaptability (figure 4) we distinguish are *artefactuality, usability, externalization, self-directedness, efficiency*, and *internalization*. Underpinning the inclusion of adaptability in the model is the notion of the usability of an artefact as a tool, from which one can proceed towards artefactuality and ritualization on the conceptual level of cultural discourse. It is there that an object becomes detached from the context in which it is used—perhaps even its everyday setting—and becomes a cultural object, sometimes even a myth where it becomes associated with a tale (see also artifacts [16, 104–111]. An artefact can also come to embody a collective custom; that is, it may become the property of an entire cultural sphere, as has happened in the cases of Fiskars scissors and Nokia cell phones. We would do well to remember Wartofsky's comparison—now classic—between artefacts and cultures: "The artefact is to cultural evolution what the gene is to biological evolution—the vehicle of information across generations" [30]; cited in Pea [31]. From the standpoint of culture this comparison should be made to include the *meme* as well, which is a unit of knowledge in the cultural heritage that can be transferred from one brain to another and which can help a person understand how fashion, ideas and knowledge are transmitted from one brain and one person to another. [5]; [6]; [7]; [8]

In terms of cultural background, adaptability should also mean identification of cultural differences and adaptation to them, whereby different technical tools and applications, as well as learning materials, would be accessible to users regardless of their cultural background. As regards pedagogical models and principles, adaptability refers to usability, which takes the form of externalization. In other words, one function of usability is that the features and characteristics of a particular mobile technology can be externalized, with this then enhancing and making more effective the autonomous efforts of the individual on the level of action, i.e., his/her self-directedness. Optimally, this will improve on the level of the individual actions the efficiency and internalization of the subject matter, phenomenon, knowledge, skill or, in concrete terms, a mobile technology or network-based application. [5]; [6]; [7]; [8]

The dimensions of adaptability also merit consideration from the standpoint of the teaching–studying–learning process that is fundamental to our thinking here. The dimension of artefactuality is linked culturally to educability and trainability, which are the ultimate objectives of the levels in the model. The dimensions of usability and externalization support teaching and teachability in a particularly natural manner. On the level of studying and studiability, it is most appropriate to develop self-directedness. Where the levels of learning and learnability are concerned, the meaningful focus might be effective internalization of what is studied and the concomitant acquisition of the desired knowledge and skills. [5]; [6]; [7]; [8]

Adaptability can be seen as a general approach for improving the usability of digital materials, among other things. It is not confined to the enhancement of user interfaces but rather is a means of facilitating the teaching–studying–learning process. The rationale behind adaptability as applied in MOMENTS research has been to reduce the cognitive load associated with the use of a particular technology, information and communication tool or mobile system. Teaching applications in particular should be easy to use so that all of a student's intellectual resources might be focused on studying and learning processes rather than on using or learning to use the system. The focal principles here are distributed cognition and distributed expertise [4]: techniques and technology should serve to reduce the user's cognitive load and to remove all unauthentic, unnecessary work so that the individual will have the chance to better concentrate on tasks that require higher mental functions. [5]; [6]; [7]; [8]

The following section examines the third main component of the metamodel, interaction, and its principal sub-concepts.

5.3 Interaction

Interaction is the third main component of our integrated metamodel. On the level of cultural discourses and practices, it refers to interaction between cultures, to interculturalism and to cultural backgrounds. Interaction is reflected in adaptability as accessibility. On the level of pedagogical models and principles, interaction is seen as part of the influence and communication within and between organizations. Interaction relies heavily on pedagogical models and principles, with implications for usability and externalization and, thereby, for the success of the individual in the teaching–studying–learning process. [5]; [6]; [7]; [8]

On the level of action, interaction refers to activity and communication between individuals. These could take place between individuals, within a group or between groups. Interaction is also important for networking, the studiability of subjects and skills, and the efficiency of activities. Despite the apparent contradiction in the term, interindividual interaction in no way runs contrary to the development of self-directedness; interaction is needed in any case. On the level of individual acts, interaction is interaction between technology or media and the individual, and, naturally, between individuals. It is reflected in the individual's actions and learning, with the usability of the technical tool for its part appearing in how the characteristics of that tool can be internalized. For the individual, interaction also always brings in considerations of identity. The three main components of the MOMENTS metamodel—culture, interaction and adaptability—clearly also interact with one another. In the section to follow, we present some of our research findings that have prompted adjustments to the metamodel and thus contributed to its present form. [5]; [6]; [7]; [8]

5.4 The Interrelationship of Culture, Interaction and Adaptability

Where usability of a technical tool is concerned, the decisive factors at the concrete level are how fast and easy it is to use. These factors have a direct impact: on the level of cultural discourses and practices, if the accessibility of mobile tools or digital materials improves—with a concomitant increase in their usability owing to enhanced user friendliness—these tools and materials will be used more quickly and readily. This in turn will prompt increased confidence in their use and trust towards other users. Interaction, collaboration and communal spirit also increase in the process. (figure 5)

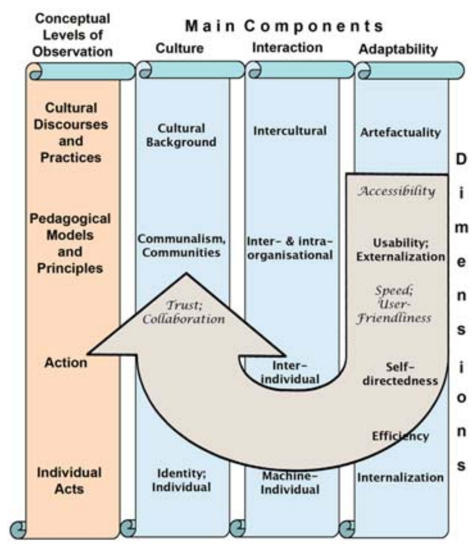

Figure 5. An example of the information work value chain linking the dimensions of the main components.

Koskimaa and Heinonen [32] point out insightfully that as the integrated metamodel represents a recent development within a framework of lifelong and lifewide studying and learning, accessibility must encompass a broad range of considerations. In their view, just as public buildings must provide access—wheelchair ramps, automatic doors, sufficiently spacious elevators, etc.—so, too, access and availability criteria must be set out for web pages, for instance, the opportunity to listen to text in addition to reading it. These issues are important not only from the standpoint of equity but also because the new mobile technology and related applications offer significant benefits in this domain. [32]; [5]; [6]; [7]; [8]

This positive development among the main components of the model we term the information work value chain (figure 5). Its positive impacts are reflected on the concrete level as the increased meaningfulness of using tools, exploring studying materials and, in turn, as more efficient working and heightened efficiency. Taken further to the level of individual actions, one may see improved and desirable learnability. We have presented these findings in figure 5, in which the information work value chain comprises accessibility, speed, user-friendliness, trust (and confidence) and an increase in collaboration and communal spirit. We would further contend that such chains represent the procedural mechanisms that are needed when new knowledge or skills are to be constructed. [5]; [6]; [7]; [8]

Our research findings on the connections between interaction and communalism (we have borrowed the term from Castells [36]) indicate clearly that the importance of technology is increasing steadily in interaction between people [32]. Its importance becomes overwhelming in situations where flexible activity is constrained by time, place or situation. The technology does not in itself create interaction, for this always requires communication between people [33]; [34]. Communication is based on people's motivation, their desire to participate and to interact with one another. We have determined that virtual spaces for communication and studying support collaboration, communal spirit, and communalism. This increases, for instance, when real-time on-line tools are used. When the technology functions smoothly and is easy to use, communication becomes easier and interaction increases. The increase in interaction frequently contributes to enhanced confidence, trust, and openness. Without these, it is difficult to build up genuine collaboration. [5]; [6]; [7]; [8]

6. FROM AN INTEGRATED MODEL TO A GLOBAL METAMODEL AND M+I+T++ COMPONENTS

In the MOMENTS project, about a dozen different types of case studies and experiments in different organizations have been carried out. In this research, a variety of shared multi-, inter- and transdisciplinary theoretical backgrounds have been employed as well as the conceptual levels of observation, the main components and the dimensions of the integrated metamodel.

As our research progressed, it became evident that more extensive angles of examination than the original main components—culture, interaction and adaptability (figure 1)—would be required. Network-based mobile education has to be contemplated from multi-disciplinary, interdisciplinary and transdisciplinary perspectives, as such points of view are taking over the field (see figure 6) [15]. This development also emphasises the increasingly growing role of globalization while calling for deeper understanding of its pros and cons as a powerful undercurrent of education and training.

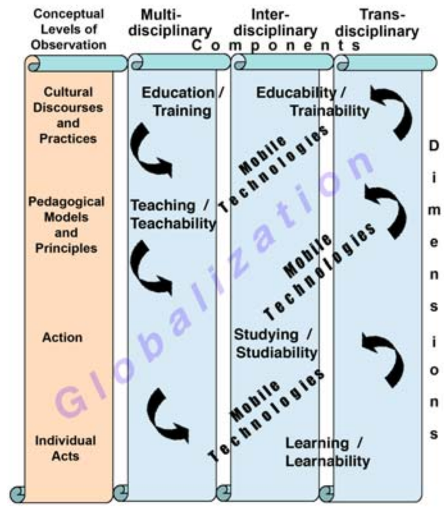

Figure 6. The M+I+T++ components of the global metamodel (Ruokamo & Tella, in [15]).

Multidisciplinary (*multi- = combining or crossing many or multiple*) research interlocks with the parallel, purposive work of many different disciplines and arts. Multidisciplinary teams do not necessarily work in close collaboration, but they take advantage of one another's points of view. On multidisciplinary teams, experts represent several disciplines, but they usually work rather independently of each other. This may lead to a situation, in which the focus of research is covered from various angles of observation, but an integrated or interactive whole might not necessarily be achieved in an ideal way. To put it differently, in multidisciplinary teams, all members represent their own fields of expertise which they would like to see highlighted, but that way the whole may not be fully or equitably covered. This may lead to a biased final result.

Interdisciplinary (*inter- = between, among, in the midst or shared by*) research makes it a point to use the methods of two or more disciplines and arts or concepts within the subject matter of one or more to solve a problem. Interdisciplinary teams are always composed of experts from several disciplines and arts. These kinds of teams work in close contact with one other, and they compare thinking and deductions systematically and regularly. Communication between interdisciplinary teams and team members is usually characterized by frequent use of tools, methods and instruments that tend to encourage information exchange and the discussing of individual results. In interdisciplinary teams, each member is expected to have his or her own area of responsibility, which at its best guarantees that the whole problem area is usually covered better than in multidisciplinary teams.

Transdisciplinary (*trans- = across, beyond, through or so as to change*) research—in other words, that which crosses scientific boundaries—aim to consciously exceed the limits of many different disciplines or arts in a purposive manner in terms of research methodologies, themes, and the research teams themselves. In their communication, interaction and other activities, transdisciplinary teams especially attempt to ensure that the different fields of science and art and their representatives interact synergetically all the time. The interactivity and integration of action are best fulfilled through communal and shared interaction. Transdisciplinary teams often include experts from neighboring fields of science or domains of knowledge, as well as "laymen", such as parents. This factor is likely to pertain to the sharing of roles somewhat differently from interdisciplinary teams, for instance. Briefly, we argue that in inter- and transdisciplinary teams, their members are more closely interdependent than in multidisciplinary teams, in which individual members keep more of the autonomy. Therefore, especially in transdisciplinary teams, the single members must really commit themselves to the aims and goals of the teams, and to help and support one another on a regular basis. [7] [http://www.teachersfirst.com/sped/parents/preschool/eric-toddler.html, http://www.basinfutures.net/susted/interdisc.htm, http://www.digitalwork.ch/transdisciplinarity/welcome.html]

7. Conclusion

In this article we have described the integrated metamodel developed in the MOMENTS project, which is part of a research program of the Academy of Finland entitled *Life as Learning*. In particular, we have examined the model's theoretical background, its conceptual levels of observation, its main components—culture, interaction and adaptability—and its other dimensions, which have emerged from its various research interests and scientific focuses.

The aim of this model is to describe, analyze and interpret the education, training, teaching, studying and learning of the future, as well as the procedural mechanisms and regularities to be seen in the construction of new knowledge. From the didactic teaching–studying–learning process and its descriptors the model has been extended to accommodate a number of key concepts, including educability, trainability, teachability, studiability, and learnability. The analysis of education/educability, training/trainability, teaching/teachability, studying/studiability and learning/learnability encompasses interventions implemented using mobile techniques and technology. We have also included the multi-, inter- and transdisciplinary research dimensions (figure 6). This is the stage which we have decided to call a global metamodel, as it can be seen as an M+I+T++ research approach to what we initially argued in favor of teaching–studying–learning processes, especially in network-based mobile education.

We hope that the MOMENTS global metamodel will contribute beneficially to the creation of a common terminology and conceptual core among different academic disciplines and areas of M+I+T++ research. We also hope that it will promote an amalgamation of the knowledge in these fields and will further serve as a framework for further case studies looking into research problems of M+I+T++ nature. We believe that our global metamodel will also serve as an important tool for knowledge management guiding not only future research but also contributing to the reporting conventions of research findings.

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Polyscopic Topic Maps-Based Flexible and Exploratory Learning

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Abstract— ***Demands to make education flexible and active call for a comprehensive restructuring of the traditional university course format. We show how such restructuring can be done in a natural and coherent way by combining e-learning with Polyscopic Topic Maps, an information structuring method which is being developed by the authors. We describe a university course model called Flexplearn which is based on this approach, and a prototype Flexplearn course where our model is currently being implemented, used and tested.***

Index Terms— ***E-education systems, flexible learning, active learning, Polyscopic Topic Maps.***

1. *Introduction*

THE task of making education flexible (regarding both what is learned and how) and active requires that we depart from the traditional university course format where a fixed syllabus is covered in classroom lectures and required of students on the exam. This re-opens a number of very basic questions such as:

- In what way do the students learn?
- How is the guidance and support for active and flexible learning provided by the instructors?
- What assumes the role of the syllabus and the textbook?
- What is the role of the lecturer and the lectures?
- What is required of the students on the exam?
- What is the grade based on?

We outline a university course model called Flexplearn which resolves those questions in a natural and consistent manner. Our proposed approach is based on the Polyscopic Topic Maps information structuring method, which is being developed by the authors.

The rest of the article is in two parts. In the first, the Polyscopic Topic Maps information structuring method is introduced. In the second, the Flexplearn university course model and the associated e-learning platform are described. We present our model by describing the University of Oslo Information Design course (abbreviated as ID course), which serves as a design prototype and a concise specification of Flexplearn.

2. *Polyscopic Topic Maps*

2.1 Topic Maps

Topic Maps is a method for organizing, retrieving and navigating information. Along with Semantic Web, the Topic Maps serve for creating a semantic layer on top of Internet resources, which allows for semantic and more efficient access [1].

The main concepts in Topic Maps are topics, associations and occurrences [2]. The associations specify in what way the topics are related with one another. By following an association, the search can move from a topic to the one which bears with it a desired semantic relationship. An example of the kind of access which is facilitated by Topic Maps might involve shifting from the topic ‘Giacomo Puccini’ to the topic ‘Lucca’ (the city where Puccini was born) and then to ‘Alfredo Catalani’ (another composer born in Lucca).

Topic Maps are considered to be a remedy for information overload [3,4].

Topic Maps have proven to be useful in e-learning and active learning [5,6].

2.2 Insights from History of Computing

The following parallel between information overload and early history of computer programming suggests that the Topic Maps method alone is not sufficient to remedy the information overload, and helps us motivate Polyscopic Topic Maps.

In the early 1950s the budding software industry found itself in a crisis. Ambitious software projects were undertaken which resulted in thousands of lines of ‘spaghetti code’ (called so because of their complex, spaghetti-like control structure) which nobody could understand or debug. The solution was found by developing high-level programming languages such as Fortran and Cobol, and programming methodologies such as structured programming and object orientation [7], which provide methods for creating and structuring easily comprehensible programs.

The conditions around information are now

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similar. The new information technologies have allowed us to produce enormously large quantities of information [9]. When we now structure information by using the techniques which were developed for much smaller quantities, chaos results [9,10].

Indeed, the initial version of the World Wide Web has provided hypertext as a tool for modular structuring and hyperlinks as an equivalent to program control. But we presently have no underlying metaphor or principle which would help us structure information. Furthermore, from the point of view of our parallel, the hyperlinks are quite similar to the GOTOs (they allow for arbitrary jumps from one context to another), and so are the Topic Maps associations. The consequence is that the Internet information is currently structured in a spaghetti-like manner, similar to early computer programs.

What is needed is a collection of structuring principles and techniques, analogous to the ones introduced by early programming methodologies. Those are provided by the Polyscopic Modeling information design methodology.

2.3 Polyscopic Structuring of Information

Polyscopic Modeling is proposed as prototype *information design* methodology [11,12,13]. Polyscopic structuring of information is one of the key elements in this methodology. In keeping with the basic principle of programming, polyscopic information is structured in terms of small, manageable modules, each representing a simple *coherent view,* as explained below.

The polyscopic structuring of information is based upon the notion of *scope,* which may be understood as a viewpoint or a way of looking. Multiple scopes are considered as possible and even necessary. The *scopes,* and the associated *views*, can be either *high-level* or *low-level.* The *high-level views,* like the high-level modules in a hierarchically structured program and the view from the top of a mountain, present the large picture. The *low-level views* present the details. As in a structured computer program, the *high-level* modules provide the structure for organizing the *low-level* modules. At the same time, the *high-level* modules provide the context and the motivation for the information contained in the *low-level* modules.

Obviously, the polyscopic structuring of information involves more than just reorganizing the existing information. The lacking *high-level information* needs to be created. The missing *low-level information* needs to be created and the existing one needs to be reconfigured. The Polyscopic Modeling methodology provides the principles, criteria and methods that are required for this task [12,13].

In addition to *vertical abstraction* whose goal is to create the *high-level information,* the methodology also supports *vertical abstraction*. Polyscopic information is presented in terms of different *aspects* which intuitively correspond to 'sides' or 'angles of looking'. The *aspects* may reflect different reader categories, ways of looking at the subject etc.

The main principles of polyscopic information structuring may be formulated as follows:

- Information exists on all levels. Both *high-level* and *low- level views* must be provided (vertical abstraction).
- Information has multiple *aspects*, some of which are subtle or hidden. The most relevant *aspects* must be provided (horizontal abstraction).
- Information is a function of the way of looking or *scope*. The *scope* is *coherent* if it represents a single level of detail and angle of looking (or intuitively, if it reflects a single viewpoint on the metaphorical mountain). Each information module must be associated with a single *coherent scope* (coherence).
- The awareness of the *scope* is crucial for proper understanding (intuitively, one must know where on the metaphorical mountain one is standing when looking at a piece of information). Each information module must be associated with a clear and correct representation of the *scope* (orientation).
- The *scope* determines the *view* (intuitively, the *scope* is the control knob given to the reader to switch between views). The reader must given the capacity to select the view by changing the scope (navigation).

To see the naturalness of the polyscopic structuring of information, it is useful to think of inspecting a hand-held object. Naturally, one uses the capability of the hand to turn the object at different angles and take it closer or further from the eye to explore the object. In a similar way, the polyscopic information structuring gives the reader the capability to select *scopes,* in order to facilitate the exploration of the presented subject.

Polyscopic information structuring supports the 'holistic' or 'multiple-perspective' thinking. This way of thinking is especially relevant in the post-industrial era, where it has become increasingly important that both technical, socio-cultural, political and other aspects of an issue be taken into account in decision making [14].

2.4 Making the Topic Maps Polyscopic

The Topic Maps provide a natural platform for polyscopic structuring of information. The instance/type and the subclass/superclass constructs allow for vertical abstraction and for implementing the *levels*. The scoping constructs allow for horizontal abstraction and for implementing the *aspects*.

The Polyscopic Modeling methodology provides principles for structuring the Topic Maps in a polyscopic way. To use again our parallel, the Topic Maps are in the role of a low-level programming language. The goal of Polyscopic Topic Maps research is to create standard structuring constructs analogous to the DO-WHILE and the IF-THEN-ELSE control statement. While a systematic account of this research would at this point be premature, for the purpose of our educational model a simple Polyscopic Topic Map prototype is sufficient. In this prototype, the hierarchy of *levels* is implemented by providing the taxonomy, which is a hierarchical organization of the main concepts involved (Figure 1). The *aspects* reflect the user interests and profiles, ways of looking at the material covered and the kinds of information that is being presented.

3. FLEXPLEARN COURSE MODEL

We now describe the Flexplearn course model by describing the University of Oslo Information Design course (INF3210/4210, in further text 'ID course'), which been developed as a prototype and a test case of Flexplearn.

3.1 Subject of Study

The subject of study of the ID course is *information design,* understood as conscious and purposeful use of information and information technology. The course includes a broad spectrum of related themes such as visual literacy and graphic profiling, software tools such as the Macromedia Dreamweaver and Adobe Photoshop, motivational issues such as relativism and information overload, philosophical, social and political issues around information creation and use etc. The methodological approach to information, represented by the Polyscopic Modeling methodology, serves both as the unifying theme and as the source of guidelines.

It is not difficult to understand the need for this type of course. Academic communication cannot remain restricted to books, articles and other traditional presentation formats. Students need to learn how to use the new media technology. But even if one wants no more than to learn how to create Web pages, proficiency with Web design software will not be sufficient. To be able to communicate in a new way and to truly exploit the advantages of the new medium, one needs to look more deeply into the very nature of information, learn about various elements of visual communication such as colors and fonts, about information structuring and navigation etc.

Furthermore, in the Age of Information, students need to learn about our changing information needs, subtle psychological and cultural effects of information and understand how information is related to economic and political power.

The methodological approach to information further leads to the creation of new methods for stating and proving research results [15]. Exposure to the methodological approach can help the researcher in a traditional field broaden the repertoire of themes and methods, and the researcher in a new inter-disciplinary field develop the required methodological framework.

3.2 Students

The student population of the ID course is highly diverse. At present the course has about 120 enrolled students representing a broad range of backgrounds and interests. The students are in part computer science majors (that being the department where the course is taught) and in part majors in a variety of departments around the University of Oslo campus. Some of the students are working full time. The course can be taken both on the undergraduate and the graduate level. We are also planning to extend the course internationally.

This diversity of student situations, backgrounds and interests further motivates our flexible learning approach.

3.3 A Flexible Learning Environment

The notion of a *flexible learning environment* is central to the Flexplearn model. The purpose of a *learning environment* is to provide a variety of *learning resources,* and a rich and inspiring environment in which learning happens in a number of ways, not the least by actively exploring a certain theme or themes of interest.

The flexibility is both with respect to the time and place of learning (a sufficient part of this environment is available online to make distance learning feasible), and with respect to what is learned (the students learn according to their own needs and interests).

The ID course provides a *flexible learning environment* for studying *information design.* Students learn from one another, from the instructors and from the online and other resources. The main role of the course instructor is to set up and coordinate the *flexible learning environment*. Standard tools such as a Wiki and a discussion forum are provided. Other tools are being designed and experimented with.

Whenever possible, the *learning resources* are made available online. A resource is made available by 'placing it on the map' (the ID course Polyscopic Topic Map). The course Polyscopic Topic Map is where all the online *learning resources* can be found.

An example of a *learning resource* may be a guest lecture about Topic Maps which discusses the information overload as motivation. This lecture is videotaped and placed on the map as a topic. Suitable associations with 'standards and markups' in 'tools', and with 'information overload' in 'issues', are added to this topic. The Topic Maps lecture can then be accessed both by scanning through the 'lectures' aspect of the map and by following the associations from any of the associated topics. In this way the student who may be interested in, say, the information overload, can easily access all the *learning resources* that are associated with that topic.

3.4 The Course as a Design Project

A salient characteristic of the ID course Flexplearn *environment* is that the students learn (in part) by co-designing this environment. In the ID course the students learn *information design* by designing the ID course and the course materials.

The course instructor has the role of the head designer, facilitating and coordinating the individual projects.

3.5 Student Projects

The students organize themselves into one to four person groups with the task of doing term projects. By participating in projects, the students learn *information design* in two ways: by exploring a theme which is of interest for *information design,* and by presenting this theme by using *information design* methods and tools.

The goal of each group project is to create a polyscopic presentation of the explored topic area. A student group might, for example, take a technical theme such as the Adobe Photoshop, about which a lot has already been written and published online. Even then the group will be able to do creative and useful work by:

- Creating a brief *high-level* presentation of Photoshop. The main goal is to present Photoshop to the students in the course so efficiently that within minutes of reading one is able to understand what Photoshop is all about and what tasks it may be good for.
- Organizing the best available resources (texts, tutorials, examples etc.) as *low-level* data. Here the goal is to select and organize the available learning resources and provide efficient and easy access to those resources.
- Learning and using the state-of-the-art information design tools to accomplish the task. Often the students will use Flash, XML and other tools and techniques to create the *high-level view* and to structure information and implement the navigation. In this way the students are given an opportunity to learn the technical tools and to use them in the *information design* way.

The ID course Polyscopic Topic Map serves as a platform for orchestrating the project work. The students are told that, when organizing their project groups, they are in a similar position as the globe explorers five centuries ago. The ID course Topic Map reflects the current status of our knowledge about *information design* ('the world as we know it'). The students' task is to organize an 'expedition', venture into a part of the 'map' of their choice, explore it and bring back knowledge and resources. Based on everyone's findings, we supplement, refine and re-create the map for the next generation of students.

Naturally, the ID course Polyscopic Topic Map provides also the 'containers' for the knowledge and the resources resulting from the student 'expeditions'. At the beginning of the term each student obtains a personal map, which is then used for keeping track of the 'itinerary' and for placing the resources (books and articles, online tutorials, insights etc.).

The result of each student 'expedition' is a project website and its documentation. In addition, each student produces a personal report.

3.6 Lectures

Two kinds of lectures are provided: classroom lectures and group lectures. The classroom lectures are focused on the basics of *information design,* the material which constitutes the academic core of the subject. The group lectures are intended to provide support for project work. They give a systematic overview of *information design* tools and techniques.

The classroom lectures are taught by the class instructor and guest lecturers. They cover such themes as 'tackling the information overload', 'Information, Not Manipulation' and 'Creation of Meaning'. The guest lecturers represent a broad variety of backgrounds and vocations.

The group lectures are taught by two teaching assistants. One of them (presently Fredrik Refsli) is a graduate student in the Norwegian School of Art and Design. The other teaching assistant (presently Rolf Guescini) is a graduate student in Computer Science and Linguistics. Fredrik covers systematically such themes as visual thinking and graphic profiling, and tools such as Photoshop, Illustrator and Framemaker. Rolf covers the more technical subjects such as XML and PHP.

Some of the group meetings are reserved for hands-on help. The students bring their home computers or use the ones available in class, show their projects and ask questions. The teaching assistants walk around and give help and advice.

3.7 Exams

Presently, the course has a small take-home midterm and a combined take-home and oral final exam. We are planning to experiment with other evaluation forms, including more frequent online ones.

The midterm task is to set up the project team and theme and describe the itinerary for the personal and team journey. Each student draws her personal itinerary on the ID course Topic Map and describes the milestones and the personal interests and goals. One of the effects of this midterm is that the students become familiar with the Topic Maps and with the ID course Topic Map.

The individual take-home final is limited to four pages of text. The student answers several fundamental questions about *information design,* and further questions reflecting her participation in the group project. Before the oral exam, the instructor and the teaching assistants examine the group projects and individual take-home exams, make comments and give tentative grades.

The members of each group take the oral exam together. The exam consists of a ten-minute project presentation, followed by questions addressed to individual students, which are based on each student's personal itinerary through the ID course Topic Map.

3.8 Grading

The student's personal itinerary through the ID course Topic Map allows us to tailor the grade to the student's own learning path and depart from a fixed syllabus.

The grade in the course reflects 50% what the student has taught others (by participating in the project and in other ways) and 50% what the student has learned from others.

4. CONCLUDING REMARKS

What has been said about Polyscopic Topic Maps and about our Flexplearn course model allows us to discuss the advantages that Polyscopic Topic Maps offer when used as a basis for flexible and exploratory learning.

To see the usefulness of Topic Maps in this context, it is sufficient to draw conclusions from our parallel: If the student should be allowed to depart from habitual learning paths and explore new terrains by following her own needs and interests, what could be more natural than to provide a good, reliable map as support for such journey? As we have seen, such a map can also allow the student to present the trajectory and the results of her explorations, and the instructor to conduct a customized exam.

The question remains, why should the Topic Maps for flexible and exploratory learning be polyscopic? There are several ways to answers this question. One of them follows directly from our parallel: The geographical maps *are* polyscopic. They have *levels* (of detail or granularity), each serving a different purpose. They also have *aspects*: physical, political, climatological and others. For very similar reasons, the guidelines for flexible and exploratory learning also need to be presented polyscopically. The *high-level view,* like the coarse-scale map or the view from the top of the mountain, provides an overview and allows the student to choose the general direction. The *low-level views* provide more concrete guidelines in terms of *learning resources.* The *aspects* serve a similar end as in the geographical maps, namely for distinguishing between various usages and different kinds of information presented.

Another reason for using Polyscopic Topic Maps is that this allows us to take care of the prerequisites. While learning is no longer restricted to a fixed linear path, which would naturally allow for presenting the material in the required order, the order is now maintained by requiring that *higher-level* nodes in the Information Design taxonomy (Figure 1) are studied before the *lower-level* ones. It is natural to present the foundations and general insights as *high-level views,* and of the material for more in-depth study as *low-level view.* When the *learning resources* are placed in a hierarchical *taxonomy,* as it is the case in the ID course, then the students can easily orient themselves by first learning the parent nodes and then the *low-level* ones. This also supports learning at the right level of generality, which is efficient.

Polyscopic Topic Maps support good thinking and learning habits. The *levels* allow us distinguish what is fundamental from what is ephemeral, the large picture from the detail. The *aspects* allow us to control the complexity by distinguishing between different angles of looking (technical, humanistic, philosophical etc.) while still keeping them together.

The Polyscopic Topic Maps are particularly suitable for multi-disciplinary, inter-disciplinary and trans-disciplinary learning and research. They allow for overcoming the separation between the humanistic and the technical aspects of an issue, which needs to be encouraged [14].

During the brief history of e-learning, the systems which are relatively straight-forward online implementations of the conventional class

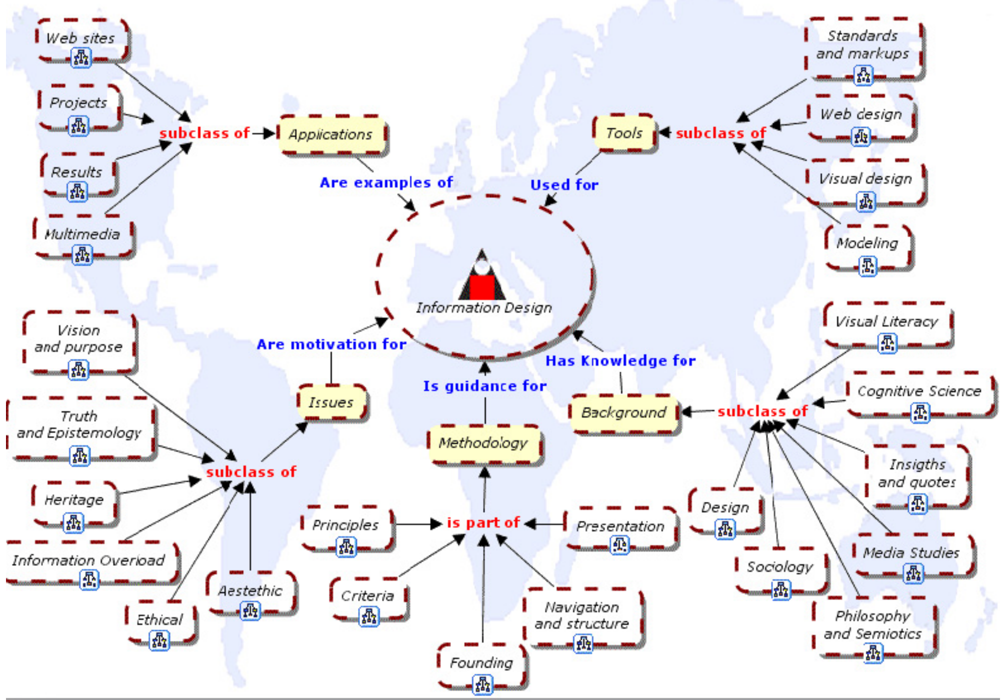

Figure 1: Information Design taxonomy.

model have been received in practice with varying degrees of success. Our Flexplearn course model is a result of a different approach where a completely new learning model is developed, which on the one hand exploits the advantages of the available technology, and on the other hand employs the known principles of good learning. The still limited practical experience with the Flexplearn suggests that this might indeed be an approach to e-learning which 'works'.

The approach taken in the development of Flexplearn can be generalized and applied to other tasks [16].

Our final remark is about the Flexplearn approach as a course development strategy. Initial experience suggests that Flexplearn may provide a productive and inspiring *flexible learning environment* also for a large number of enrolled students. Economies of scale can then warrant the use of additional resources, inviting international speakers, investment into state-of-the-art communication design etc., which would then further increase the chances of creating a productive and inspiring *flexible learning environment*.

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Neurobiological and Transformational Learning

Janik, Daniel; Bills, Margaret.; Saito, Hisako; and Widjaja, Christina

Abstract—*Departing radically from 2000 years of Platonic teaching tradition, the authors argue for the existence of a single, neurobiologically-based theory of learning (NL) underlying the more than fourty contemporary teaching and learning theories. This new, 'brain-based' learning theory is derived from clinical experience with psychological recovery from trauma coupled with contemporary medical imaging information on how the brain learns 'effectively.' The role of trauma in teaching is examined. When applied in the subsequent language acquisition classroom, the authors observed the emergence of a 'non-traumatic,' curiosity-based, discovery-driven, mentor-assisted, transformational form of neurobiological learning (TL) and provide select observations of interest. The authors conclude that NL and its derivitive, TL, may be the foundations of the long-sought 'unified educational theory,' the next logical step in humanity's slow but steady movement beyond traumatic, institutional, national and ultimately planetary boundaries of education.*

Index Terms—*Neurobiology, Neurobiological, Transformational, Teach, Trauma, Brain-based, Learning.*

1. Introduction

Medicine and public health have successfully resolved many 'classical' epidemics, such as puerperal fever, and milk-related disease. More recently, they have begun addressing peptic ulcer disease, heart attacks and stroke, smoking, alcohol consumption, gun control - even longevity. Yet, interestingly, one of the oldest human nemeses, violence - in medical terms, psychological trauma - and its widespread consequences, although acknowledged, continue to elude us [1,2]. Even more interesting, is the recent appearance of this specter in the guise of 'effective' teaching within educational institutions - in short, the institutionalized impression of the ideas of one person (a teacher) onto another (the learner) as effectively and efficiently as possible [2-5].

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2. The Liabilities of Effective Teaching

That teaching may have limitations or even liabilities is not a new idea. The presence of myriad educational theories (over 40 just within linguistics alone), each applicable to a limited domain is alone highly suggestive [4]. That parents, schools, educational boards, states, societies and nations are currently engrossed in issues of assessing teaching curriculum and quality, speaks further to this issue. C. P. Snow in his now famous work, *The Two Cultures*, identified within contemporary higher education a disturbing 'loss of creative zest' [2, 5, 6]. To these, we add that effective teaching, as practiced in many educational institutions today, by its traumatic nature invokes traumatic learning along with its attendant side-effects: exhaustion (repression, depression and 'burnout'); obsession with learning contracts, curriculum and lesson plans; overemphasis on student and classroom management; compulsive need for quality assurance; and the maintenance of a constant level of anxiety and often fear through testing and evaluation [2, 5].

If 'effective' contemporary teaching is, in fact, traumatic and so ubiquitous, where does it come from? Why are we so blinded to its traumatic nature?

3. The Origin of Teaching Trauma

Otto Rank, in his seminal work, *The Trauma of Birth*, provided the first clue: Traumatic inculcation and learning are imprinted experientially in humans at birth [6]. Teaching, when most 'effective,' copies, invokes and reinforces effective survival learning reflex patterns assimilated from birth [2, 4, 5, 7]. Given the ubiquitousness of the birth event, can there be any wonder that educators, teachers, learners and parents are at the least partially blinded to trauma, teaching, traumatic learning and their effects?

Ever since Plato broke from Socratic tradition and formed his famed Academy and institutionalized 'traumatic' teaching, it has co-evolved both with and within us [4, 5]. 'Effective' traumatic teaching has become pandemic to the extent that it is difficult these days to conceive of a non-traumatized control group!

Nonetheless, we theorized that in attempting to co-understand the processes of 'effective' traumatic learning involved clinically and within the human brain, we might be able to construct a fundamental, theory of effective learning that might underlie the many educational theories and methods [4, 5].

4. *The German School of Effective Learning*

We therefore turned our attention from Platonic-based, primarily ideational, British-American learning theories to Socratic-based, neuro-sensory, medical-physically-based, learning theories in the German tradition and proceeded to investigate what we call neurobiological learning (NL) [2, 4, 8, 9]. Following in the footsteps of the physician-neurolinguists Gall (1758-1828), Bouillard (1796-1881), Broca (1824-1880), Wernicke (1848-1905), Jackson (1834-1911), Kussmaul (1822-1902) and Freud (1956-1939), as well as educator-linguists interested in the neurobiological foundations of learning such as von Humboldts (1667-1835), Schleicher (1821-1868), Muller (1823-1900), Steinthal (1823-1899) and Lenneberg (1921-1975) - the so-called 'new' German School of neuroanatomical linguists, our hope was that incorporating contemporary medical-clinical knowledge of the psychological processes of recovery from trauma along with concomitant medical imaging information, would eventually lead us to a second, *non-traumatic* form of effective learning [2, 4, 5, 8]

The first author, in his academic monograph, *A Neurobiological Theory and Method of Language Acquisition,* described what may be the first cohesive theory of NL, complete with natural laws (tenets), attendant methodology, and a description and evaluation of its in-classroom application at Intercultural Communications College in Honolulu, Hawaii, USA [2, 4, 5].

5. *A Second Learning Pathway*

One result of classroom application of this work was the slow evolution of an alternative, non-traumatic, 'second learning pathway.' Curiosity-based, discovery-driven, mentor-assisted, and distinctively transformational in nature, we called this derivation of NL transformative learning (TL) [2, 4, 5]. We are now pleased to present some of our more interesting observations in applying TL theory in the subsequent language learning classroom at our institution.

5.1 Peripheral versus Central Learning

In rethinking the classroom neurobiologically and transformationally, it quickly became apparent that we could not expect to 'teach' learners near-native grammar, structure, discourse, communication and interpretation. We could, on the other hand, strengthen individual curiosity, pre-discovery, discovery and critical thinking skills *in the subsequent language*, introducing semantics, lexis and discourse peripherally [2, 4, 5]. The result was that learners became largely free to choose their own learning topics. When, during use in our subsequent language classrooms, learners brought up semantic, lexical or discourse questions, it required energy on their part to centralize, define and communicate their questions in the subsequent language, pursue an answer and make an individual or collective discovery. This alternative pathway appeared equally, and in some instances more effective than traumatic introduction of a central learning object [2, 5].

5.2 Learning Contracts, Lesson Plans and Curricula

The overall result was a substantive reduction in reliance on learning contracts, curricula and daily lesson plans at the expense of greatly expanded teaching resources. Interestingly, the internet proved to be an excellent learning resource, at least within this framework, providing innumerable peripheral learning opportunities. In this manner, NL/TL learning occurred around 'authentic,' physically-based student experiences rather than teacher ideas.

5.3 Expanding the Neurosensory Repertoire

NL events proved well grounded in the five classic senses (smell, vision, hearing, touch, taste) to which, over time, we added two more: kinesthesia (internal body sensation) and time consciousness [2, 4, 5, 10, 11, 12]. The later in particular imparts perception of change over time (rhythmicity in association with kinesthesia, for example, in dance, one of the classical learning forms) [11, 12]. Expansion of the neurosensory repertoire has opened up a wider variety of appeals to learning. We believe that the richness of NL/TL theory in application (as in this example) supports our thesis that it represents a useful, productive and fundamental education learning theory.

5.4 Pre-Discovery Dysesthesia

A particularly interesting observation is that discovery was uniformly preceded by a difficult, often stressful (dysesthetic) period of pre-discovery [2, 4, 5, 10, 11]. According to classical teaching theory, pre-discovery dysesthesia should lessen and eventually disappear with repetition and increasing command. NL/TL, on the other hand, posits the pre-discovery phase as uniformly *necessary* for the 'Pop Out Phenomena' (and thereby discovery) to occur [2, 4, 5, 13]. Our indicator of success around pre-discovery disesthesia became the development of a gradually increasing tolerance and eventual recognition, appreciation and acceptance of pre-discovery dysesthesia as a prelude to discovery *as modeled by the mentor*.

5.5 Neurobiological Truth

In NL vocabulary, our goal changed to that of 'welcoming' pre-discovery and learning to 'trust' that one's curiosity and searching would be rewarded [2, 4, 5]. As a result of this process, we found that discovered 'truths' developed as a holistically plastic rather than ideationally concrete phenomenon. Learners tended to relate the measure of kinesthesia experienced during discovery, at least to some extent, with a sense of felt 'trueness.' This is quite different from classical teaching.

5.6 Characterization

In traditional teaching terms, NL/TL has been characterized as serendipity, event-driven, content-based, reconstructionist and even eclectic [2, 4]. These same observers, however, often comment on the unusual way our learners 'use' mentors. Our learners relate to the *mentoring process* rather than learning contracts, teacher ideas, lesson plans or curricula.

5.7 Mentoring

It quickly became clear to us that mentorship was the 'glue' that binds TL and makes it work. NL/TL-based mentoring is, however, somewhat different from the contemporary concept of mentoring within teaching. For example, mentoring under NL/TL is equally effective whether the mentor knows the answer to learner questions or not. In fact, not knowing an answer (1) creates an opportunity to demonstrate curiosity and inquiry, (2) provides learners an opportunity to observe the pre-discovery, (3) allows them to test whether discovery really will take place, and (4) observe and want to experience the joy that discovery eventually brings.

5.8 Law of Learning Conservation

With TL, there appears to us to be a Law of Learning Conservation: Nothing is lost; everything becomes a learning opportunity [2]. This brings up a question that invariably surfaces among new NL/TL mentors: What if my learners do not engage in learning? Some 'newcomer' learners might have become so accustomed to being given questions and answers - to being entertained or 'taught' - that they no longer engage their natural curiosity [2, 4, 14].

We encourage all, but especially 'newcomer' learners to question everything. Everything - especially anything said. Classical teaching suggests this would result in chaos and be a demonstration of the teacher's lack of ability to control students and manage a classroom. Our NL/TL mentoring experience, on the other hand, clearly indicates that *this is where learning begins*, and when curiosity is engaged, student control and classroom management become unnecessary hindrances to discovery.

5.9 Testing and Evaluation

In implementing 'volitional' NL/TL learning, the issue of student testing and teacher evaluation always surfaces. Testing and evaluation are, by their nature, largely non-volitional and thereby traumatic. Some might say that it is their traumatic nature that makes them effective teaching tools [2, 4]. Despite an a priori resistance to the incorporation of testing and evaluation in the NL/TL classroom, it was of great interest to us to compare NL/TL learning and classical teaching outcomes. Over time, we found Delphian-style capstone projects an outstanding way of non-traumatically 'testing' individual and small group learning. 'Delphian-style' refers to the use of progressive class consensus, rather than fixed, external values to measure learning; 'capstone project' describes elective learner participation in a 'final' project that demonstrates each participant's ability to use and apply (rather than identify and understand) the learning elements used by a particular group, at a particular level with regard to a topic.

Evaluation, on the other hand, 'devolved' into two parts: After completion of a Delphian capstone project, learners provide feedback to mentors by electively answering four open-ended questions: (1) What will you always remember about this class? (2) What one thing did you like BEST about this class? (3) What one thing did you like LEAST about this class? and (4) Write a suggestion about how to make this class or instructor better. Second, mentorship is held to be reflected in the nature and extent of each mentor's voluntary participation in peer-reviewed professional activities – a 'natural' outcome of self-applied mentorship.

6. Unified Learning Theory

Given the broad swath of NL and TL, we felt free to incorporate whatever 'fashion' theory, method or technique that worked in any particular situation. This may or may not seem surprising, but to us it was interesting how easily other educational theories and methods could be implemented non-traumatically yet effectively *within an NL/TL framework*. Without the NL/TL framework, this is not usually the case. We regard this as further evidence that NL and perhaps even TL may truly underlie other 'effective' teaching theories and methods.

Our mentoring group at ICC come from diverse academic and educational training backgrounds, yet, I think it fair to say that as a group we have become increasingly convinced that curiosity-based, discovery-driven, mentor-assisted, transformational learning (TL) has a distinct, and, we surmise, significant, central role to play in contemporary education. Furthermore, we believe NL/TL capable of providing a rich theoretical framework not only in the classroom, but within tutoring and even distance learning venues [2, 4, 5]. Towards the latter end, we have developed, implemented and are now evaluating a distance learning application first implemented at ICC in 1997 that we call 'TOEFL by Internet.'

7. CONCLUSION

NL and its derivation, TL, we believe, may represent the long sought after unified educational theory not only of the post-methodological educational era, but also of the 'next generation' of education - that of 'digital' education, without walls, over extended times and distances - the next logical step in humankind's slow but steady transition beyond geopolitical boundaries and even those of our planet.

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The Management of Personnel Collaboration for the improvement of multidisciplinary projects

Lepage, A.

Abstract—***Which perception keys of multidisciplinary team members' collaboration would assist engineering project leaders in decreasing it's performance variability? The study of leadership and psycho-sociological tools in the labour-knowledge field makes it possible to produce a synthetic typology of team members' profiles, adapted to the team's design aim depending on the stake, the role and the crisis condition in the organisation. In order to model the effectiveness of the team, the methods of team member reliability measurement are linked to the profiles of the team members in relation to the crisis context of the project. The research analyses the performance of the model applied to real projects in companies, with a particular emphasis on innovation.***

Index Terms—***psycho-sociology in labour, project management, multidisciplinary team, team member collaboration***

1. The problem of team member selection for a project

Today a major stake in companies remains the selection of the team members for a project. Good collaboration between the members of the multidisciplinary team has become a very significant concern of the project leaders. But, as presented in part 2, psycho-sociological knowledge reveals a too wide diversity in peoples' profiles, and team leaders, particularly in the industrial field, are not familiar with the complexity of the management of team member collaboration (Mintzberg (1,2), Hacker (3)). Moreover, the particular context of the daily tasks in design or innovation projects corresponds to a crisis generated by the pressure to find rapid solutions, and in the difficulty of understanding between different specialists. In our research area (industrial management), we analyse data from the actual work situation within companies in which we have part-time contracts as project co-managers. So our research method is a qualitative-quantitative mix with data analysis from small observation panels of these companies and large-scale confirmation in other cases. We stop the data validation at the beginning of the saturation phenomena, respecting a beta-binomial model, and crossing internal observations and validations (in the workplace) and an outside theoretical approach (as presented to the Academy of Management, Lepage (4)).

The most frequently-asked questions by project managers, even those with good skills in human-resource management, are mainly concerned with establishing team-member profile and selection of personnel based on very simple assessment tools (less than 5 characteristics measured).

From this large range of complex tools and methods, the question of correct usage by project managers with an engineering education is posed and discussed. This is compared with newly-emerging global approaches in the art of management (end of part 2). Before stating the need to design a description of a team member's profile from the expectations of the user (part 3), we can define our problem: to develop and validate a typology of people and to make prognoses about their performance in different situations; this, in turn, may help project managers to select suitable personnel for different projects and to adopt the appropriate style of management.

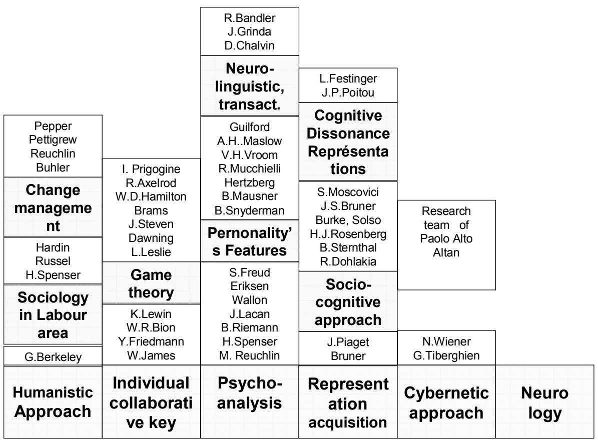
At the beginning of part 4, we present the validation of such a concern in multi-disciplinary projects in companies. Then, at the end of this part, validations are commented upon with regard to the extension of their application in innovation.

2. Available knowledge concerning collaboration in a project team

2.1 Psycho-sociological basic tools in labor field

We began our study on psycho-sociological tools and their implication in team-working. A range of topics from the work of 91 authors in the field, has been selected by the INFFO Centre (European Association of Researchers and Professionals in Human-Resource Management, La Défense, France.), from which we made a bibliographical verification. This data was mapped in 15 groups by the affinity-diagram method (K.J. method, Jiro K., (5)), in which we proceeded to structuring the topics with the research-team (experts in psychology and sociology of labour and project managers). We designed: humanistic approach, sociology of labour, the sociology of change–management, individual collaborative behaviour within the group, game theory, psycho-analysis, theory of the features of the personality, transactional analysis and neuro-linguistic programming, acquisition of representations, socio-cognitive approach, cognitive dissonance and representations, cybernetic approach, systemic approach, behaviourist approach, neurology, neuro-sciences.

In order to present these fields, these headings are gathered in 6 visible roots in figure 1, below, in which the headings at the bottom are the oldest and, those at the top, the most recent (in order to give only a synthesis, we do not mention any of the authors in detail, neither do we make any reference to them).



absolutely unacceptable for an industrialist whose aim must be to reduce its variability to less than 10%, to reach (by definition) a satisfactory outcome. In spite of these sound developments, complexity still remains too important a factor for its application to be undertaken by an industrial manager who is not a specialist in psycho-sociology.

Also, more important than the irrelevant use of simple but unreliable methods of psycho-sociology and the difficulty in applying recent work in neuro-science, both of which may be within the knowledge of project managers, we made the hypothesis that global management could offer them surer methods which are built on experience.

2.3 Collaboration and leadership

We already knew in 1960-1970 from Fiedler (20) about collaboration and leadership in his contingency theory ("leadership effectiveness depends on both the leader's personality and the situation. Certain leaders are effective in one situation but not in others"), and from Vroom and Yetton (21) in their contingency/situation theory (about 5 styles of leadership in decision making). But these concepts relate only to the subordination of human relations in task coordination by a manager who has some leadership skill , without taking into account the crisis situation arising from the context. The contingency theory has been criticised, chiefly because it depends on many different situations, without the general synthesis which we seek in our research.

We also knew from Mintzberg (1, 2, 22) about leadership. He shows that organizational design is a major input in leadership creation for continuous improvement. But, as it is true for global organization, it is not deployed in the same conditions in projects (they are self governed). The same can be observed about his analysis of failures in organizations due to lack of leadership in managers. Indeed, is what is true for global organisation applicable to projects where individual working practises are often independent of global organisation and culture? Here we make our research assumption, concerning the quality of the deployment of values, goals, and targets in a top down management with simple declinations towards the efficiency of tasks in projects taking into account the qualifications and competencies of each team member. The Total Quality Management, generally applied in the companies with which we were associated, is supposed to make correct use of this deployment (Hacker, Roberts (3)). But do all the organizations reach a high level of quality? When Pich, Loch and De Meyer (23) show that project management is made up of uncertainty, ambiguity and complexity?

Another piece of research about leadership, most closely linked to our subject was presented by Jens Dahlgaart (24): principal typologies of leadership governing the attributes of collaboration between the team members and their managers at work.

From 2001 to 2003, his team at the University of Linköping in Sweden questioned many heads and employees of European companies on the different leadership styles of the managers, acceptable to the team members in the workplace.

This questionnaire was carried out by consultants, specialising in assisting with the recruitment and evaluation of the potential of managers for companies throughout Europe.

The synthesis obtained from the vast quantity of data which was collected reveals the existence of 8 principal profiles of leadership concerning project heads and managers:

-the task orientated: a persistent, analytical, economical, leader who doesn't accept mistakes committed either by himself or other people and who doesn't listen to others very much;

-the creative: a humorous, visionary, effective, ego-driven leader, who masters many creative tools , and may be often courageous, but one who may be impulsive and becomes involved in conflicts;

-the strategist: a purposeful leader, one who has a long and middle-term view on the project as a whole, who seems to be process orientated and trustworthy;

-the captain: a competent, open, reliable and trustworthy leader, who listens readily to others and can be a good and very forceful communicator.

-the specialist: an expert in his field and calm in appearance, but one who could be pedantic and uncompromising, very resistant to change and preferring to work autonomously.

-the involved: a humanistic and empathetic leader, who listens to employees, but doesn't delegate and focuses on routines and procedures;

-the impulsive: an enquiring, actively-involved leader, one who is actively concerned about the working environment and is ready to accept change , but who is also one who takes risks, who is autocratic and domineering;

-the team builder: a tolerant, inspiring leader, one who gives feedback, support and motivation to the team members in his role as coach.

The research team commented on the interpersonal relations which existed within these profiles, and between the leaders and their employees. These provide a choice of the most effective leadership profiles, very interesting for global management, but not successfully adapted to projects, as we learned when testing it. Indeed, we observed that such personal profiles shift from one to another when difficulties arise in a project. For example, at the beginning of a project, a "team builder" member could have fair relations with others. At the project review the C.E.O. could impose to hardly react (cutting delay and costs). The “team builder” often becomes a “task oriented” controlling people and making targets hard to follow for his team members, generating bad interpersonal relations. So we need to classify the members in more global profiles remaining stable when the crisis context of the project increases.

We could comment on the new approaches to change management (Hacker, Roberts (3)) with a great concern for project management, but as shown by Dosi (25), it is difficult to measure the changes and their bearing on economic targets. What tools and methods would be used in this measurement? It is perhaps more efficient to look at the very recent arrival of a practical approach in interpersonal relations. Indeed, the psycho-sociological intervention, (G Mendel (26, 27)) is particularly interesting in order to understand the phenomena of power, stress and crisis in the teams, at the heart of our problem. It looks again at the various branches in this field by analysing their effectiveness in operation:

- The organizational approach;
- The sociological intervention;
- The “socianalysis”;
- The socio-psycho-analysis;
- The psychodynamic one;
- The psychoanalysis groupware.

Unfortunately, as he stated , none of these 6 methods is applicable to a head of project, and none of them is really reliable. Moreover, without an easily applicable and relevant method being available to the team management, we had to create our own model of team member collaboration, driven by the requirements of company managers, and as presented in part 3.

3. THE PREPARATION OF A USER ORIENTATED MODEL

3.1 Elaboration of a model of a team member’s profile

There being few people working in psycho-sociology who are specialised in the field of behavioural studies of team members in a project, we proceeded to seek answers from complementary authors. The philosophical discussion about the emergence of neuro-science (Ricoeur (28) and Changeux (29)) opened our minds to further observations concerning the behaviour of team members. The need to manage personnel (for a head of project) involves making a choice of profile of the team members, (which main categories of profile?) depending on the technical nature of the project and especially with regard to the psycho-social configuration of the team in the organisation, at the same time taking into account the perceived professional and personal life-styles.

3.2 Linking team member reliability and crisis condition.

The difficulty which arises here is the measurement of motivation, which is a global, vague, multidisciplinary concept, which generates many tools and approaches, but which is dependent on expert opinion, (in the specialism). But when we have a sample of team members (in a large company) facing the same choices, we are able to establish the ratio of the number of tasks which are accepted, divided by the number of proposed tasks and to use this ratio as a probability of motivation, in an average targeted population of team members. The experimental enumeration can be carried out by the panel from records of similar situations experienced by a team member in his work history on multiple projects. Executives in charge of personnel (research management, design management, human resources management) can take this historiographic approach by the use of these records or by using log-books about the progression of the projects (daily return of the positive and negative events: seldom used, but extremely effective).

Hereafter we can see what was structured in an affinity diagram, with data from level zero to level 3 of abstraction: level zero: that of the perceived, exchanged, tools used between the team member and an appraiser; Level 1 of abstraction: that is equivalent to the headings of our cartography in psycho-sociology (figure 1); Level 2 of abstraction: that is equivalent to the branches of our cartography in psycho-sociology (figure 1); Level 3 of abstraction: that is equivalent to some of the required categories of standard profiles of the team members (to be defined in our research).

3.3 The concept of reliability of a team member.

Here we take another look at the original definition of reliability, to adapt it to the team member in the project. We take the concept of quality as "professional qualities of the team member", i.e. a capacity to fulfil the task which is allotted to him. The qualities of the team member enable him to carry out the task and, at the same time, the quality of his work is at 100% when the task is completed. The quality of work would be x% if he carried out the task X times out of 100 times. In the other cases, he refused or failed to meet targets (results below expectations). The x% calculated is a probability of the successful completion of a task, and therefore of reliability. To define clearly and definitively the concept of quality/reliability of a team member, it is better to retain only the definition of reliability (probability of fulfilling a task between the moment t and t + dt, knowing that between 0 and t it was fulfilled), and of subsequently adapting it to the team member in the project: reliability of the team member = probability that a team member fulfils his task in a given time, mindful of the fact that we know how he and his counterparts carried it out previously.

3.4 The concept of a state of crisis

We can observe the "professional post"

according to current practices in companies, the evaluation being measured with tools available to the worksite. The setting of targets in an organisation depends on the level of the allotted role, and the setting of targets in the strategy on the stake for the task. This allows us to combine role and stake to constitute the state of crisis with the same tool used in the observed post and the team member's capacity evaluation to take responsibility for the job at the post. We can show an example measured in 3 levels (1 = weak, 2 = average, 3 = strong), in which the state of crisis can be measured by multiplying the two preceding measurements, from 1 to 9 (see figure 2).This is not a mathematical curve, but a picture in which we can see a synthetic mental representation of a work-station classification using 4 characteristics (stake, role, experience and competency which frequently happens in companies working site assessment, but the last two are irrelevant for our research).

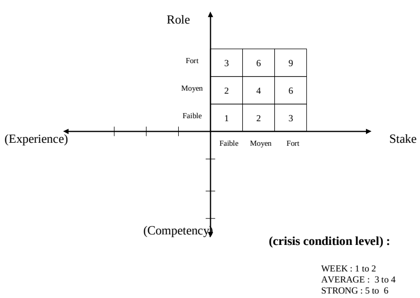


Figure2. Example of working station assessment with crisis condition classification

As we used this tool because it was available in the companies observed, we had the question of it's efficacity compared with other concepts of work-station team performance measurement. Leung, Chan and Lee (30) show one of them, but they describe the role modification (balance) when the internal project organisation is changed with regulation of work composition adapted to missing or changing tasks or personnel. Fisher, Hunter and Macrosson (31) analyses testing methods of classification of individual team members' capacities, including their performance, particularly in a team involved with new products . This very interesting approach, combined with the well known practices of the Belbin method in individual selection and motivation for team building, is very well focused on our research subject, but not particularly adapted to take the crisis condition into account.

We could now start the construction of our model. We understood, by studying the affinity diagram, that it will have two axes of dynamic representation of the evolution of the profiles: one axis for the reliability of the team members (from 0% to 100%) and the other axis for the "crisis condition" (from 1 to 9). Subsequently we give the results of the upper level of abstraction.

3.5 The person involved in management.

This is a very frequently- observed profile in project teams, both in industry and in other spheres. Its effectiveness does not often attain 100% because of its inherent failures and drifts, but it does not fall below 60% because his sense of responsibility would prevent his giving up the task. The manager likes to be involved in moderately-difficult projects and is not at ease with tasks which are either too simple or which involve unreasonable risks.

3.6 The courtier

We can define this profile as one who is more inclined to represent his company, and its project, and to communicate in situations where user-friendliness, courtesy, the ability to assume the leading role, the ability to be diplomatic, rules and traditions dominate. He dismisses the idea of even considering the undertaking of any very difficult task himself. He also usually refuses to take responsibility in times of crisis. He does not like to be involved in the long term with a team that has responsibilities.

3.7 The pioneer

This rare profile (less than 2% of manpower in normal organisations) is seeking for the "impossible mission" and sometimes the "extreme action". He sees the risk rather as a promotion of his perceptive capacities, as opposed to "normal" managers who would consider it as inhibiting their capacities. If images of highly-successful "final missions" come to mind, either from past experiences, or from envisaged future possibilities, he will undoubtedly lose his ability to listen and to discuss amicably in a standard context, thus affecting his reliability.

We graphically represented the analysis of these three profiles and their reliability according to the crisis situation on the model, figure 3, below:

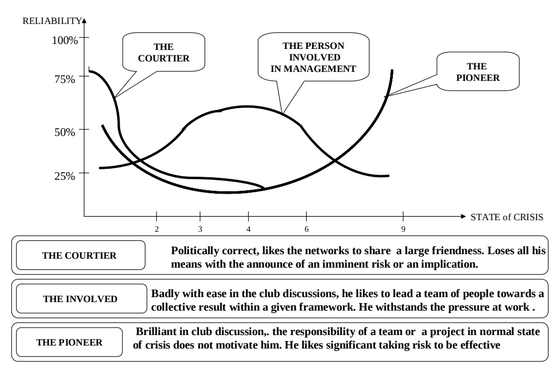


Figure3. Evolution of the three profiles according to the state of crisis

4. VALIDATION OF THE MODEL IN COMPANIES

4.1 Different validations of the model in projects

The validation was carried out in three stages, starting with a series of interviews of those in charge of organisation, of human resources and projects, according to the method of collection of factual elements named "the voice of the customer" (Griffin and Hauser (32), Lepage (33), Shiba (34)). We questioned three university professors of sociology, two of psychology, three researchers in human resource management and nine heads of industrial projects or C.E.Os. of companies

Then a "Kano" questionnaire (35) was drawn up starting from the synthesis of the first returns and was addressed (in 2001) to more than one hundred managers of companies, heads of project, including all sizes of organisation and in all economic sectors. See figure 4 the synthesis from 98 returns concerning a panel of Human Resource Managers. We can see that the HRM modified the model allowing more reliability to involved person in management in low crisis level, and less reliability to the pioneer in low crisis level. The results have been confirmed (2002 to 2004) with more than one hundred other company panels (measurement reliability 97%).

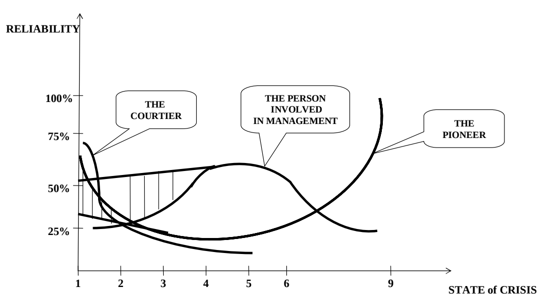


Figure4. Modification of the model by the Human Resource Managers

4.2 Discussion and extension to creativity

The outcome of this research offered a model which could finally be classified in contingency theory, because working sites and personnel profiles are assessed in each particular situation within in the companies. So, how effective is our approach, if this contingency theory has been largely criticized? We have shown in part 3 that our approach is a synthetic one at a 3 or 4 abstraction level in the area of detailed tasks, designed by many different managers in different situations, being relevant to each different case and producing the same result: in a global profile for each common case of crisis context. The validations show that the approach links the 3 synthetic profiles with the crisis condition in a reliable relation, independent of the situation.

We now extended our research, focusing on innovation projects in companies, asking ourselves the following question: "Is it opportune to preserve our typology of three profiles in the case of projects of innovation under various states of crisis?"

The state of crisis here corresponds to the need for maintaining a strong long-term vigilance and at the same time a sound capacity to perceive clearly customer expectations and solutions. This is what is shared between the managers in the context of a true-to-life working situation. Darses (36), Lundin and Midler (37) think that it would be a quite easy to share ideas, but it's not been the case in most of the companies observed. It is a question of fully engaging the personnel and to concentrate, throughout the meeting, on one subject at a time, focusing on the production of ideas and the prompt response to the proposals of the other team members.

This context, which is a crisis one, has been studied (Lepage (38, 4) in research working connected with innovation projects in 3 multinational companies. In these case studies the crisis situation is, like in most of the examples, more serious than previously stated because of a second state of crisis, replacing concentration and vigilance phenomena, which is power competition between specialists.

Concerning the creativity tools, always employed at the heart of innovation projects, we naturally extended our research as the question,frequently-asked by our industrial partners, is "Could we have a correlation between the creativity tools used in our companies and the 3 managers' profiles of our model?" As it has been shown in the innovation projects of the companies observed, we found three major creativity tools: brainstorming in "focus groups", the TRIZ method, used by one or two managers in a topic, and 'One on One' interviews of personnel (coming from the "voice of the customer" method (32,33)).

With regard to the first, many studies confirm the pointers required to ensure the success of this method of stimulating creativity: to have a talented animator (impossible to circumvent); to select personnel with "open" personalities, to ensure that participants are totally concentrated on the topic under study. Some negative points have been observed and explained by the psychologist Moscovici (39):

-the "isolated" participants, those excluded from the project at the beginning of the creativity session, remain frustrated until the end of the project and, often, prepare solutions in isolation from the group which they 'slip in' at the end of the presentation of the other principles of solution, adopted by the "focus group";

-the solutions of the "isolated" members, often drawn from previous studies and adapted for the new framework, produced the best solutions in

85% of the cases.

-the arrival of classified "open profiles ", as external elements, closed to the internal profiles, generates a self-segregation, not openly-declared but deeply felt as severe stress, and frustration.

We made the assumption that it would be more efficient to make all the personnel take part in creativity, so we analysed the productivity ideas of the three profiles in the focus group versus the creativity tool, beginning with the focus group:

-the involved person in charge, is ill-at-ease (at the beginning) in the "focus group". He wants to give his opinion in terms of the feasibility of the solutions coming from the others.

-the pioneer can be extremely productive and brilliant but must "be taken in hand" by the animator because he easily-becomes an arrogant leader, preventing the other members of the team from expressing themselves.

-the courtier is at ease in the "focus group" because he sees the situation as a friendly discussion.

Concerning the 'One on One' interview, the method is valid for the three profiles, knowing that:

-the courtier needs to be somewhat driven (by the questioner) towards the factual events that have to be described. The rhythm of the interview will resemble a mild interrogation;

-the involved person in charge will be rather inclined to dismiss his experience in favour of adopting the new ideas (although the reliable elements of past/present are maintained).

-the pioneer will have to be motivated by a constant pressure. It is necessary to make the interview factual giving very short questions to keep the person focused on the present projects as he always likes to be allowed to speak about ideas which are too far into the future.

Finally, we also had the opportunity of a trial with the "TRIZ" method (Ideation (40), conceived by G. Alsthuller, allowing a single participant (or two or three) to work on the analysis of previous ideas on the subject, to study and to modify them. This method is better suited to 'the involved person in charge'.

We can already describe the major result of these experiments in 3 companies: with the three creativity tools offered to the different profiles of the team members, we allowed all of them to participate and we observed more than 30% ideas production increasing. As we are now in the process of making this validation, we will soon be able to present our complete results, but, at the moment it is simply a qualitative description of this unfinished extension.

5. Conclusion

Industrialists' experience of the difficulty to apply the psycho-sociological tools available incite us to observe the experiment of more global leadership profiles to describe human beings of team members in project. But the stability of these profiles under different crisis conditions remains an assumption which leads us to design some stable ones at a more global synthetic level. As presented in part 3, the synthetic team member's profile, according to the state of crisis, has been validated in many different projects.

Now, it is possible to quantify the validity of our method with much more precision. Indeed, the new results, obtained in companies, on new achievements in projects of innovation, between 2003 and 2005, allow us to extend our three profiles model. In particular, the number of returns obtained and the factual nature of the information recorded by interviewing the participants in a multitude of projects of innovation, already enable us to confirm the validity of our model. And, now, the whole panel of correlations which appears between the 3 profiles and the skills of the various specialists working in the projects allows us to increase the reliability of the ideas productivity measurement. So, we are beginning to work on the concept of "maximum speed in discovering product / service solutions". We are doing this to obtain more new solutions of product/service, thanks to the convenient adoption of the good creativity methods for the team members' profiles according to the state of crisis. In particular, we are beginning to ask ourselves various questions about the impact of the concurrent engineering approaches (36) in team member collaboration in multidisciplinary projects:

-which abstraction level to choose in the exchanges between specialists?;

-can the crisis be wanted and controlled?;

-is it necessary "to enforce" the good practice in methods of stimulating creativity in order to improve the productivity of the teams, or to leave a freedom of choice to the team members and to observe the effectiveness of the team?

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A Quantitative Evaluation of Singing through Electromyography

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Abstract — *Electromyogram (EMG) measures electrical activity associated with neural firings in musculature. Such bio-signals can be used to quantify muscle activity. Since singing is a human biocultural phenonmenon, there should exist a connection between musical properties like pitch and biological parameters such as the percent of muscle usage. This study explores the reliability of EMG in quantifying the activities of Rectus Abdominis, two muscles essential to respiration during singing. Such a quantitative method is desired by practitioners for identifying one's innate singing abilities, or talent. This study also proposes a method of quantitatively identifying efficient pedagogy by comparing pre-training and post-training EMG. Our goals were to validate the method and to provide reliable criticisms for analysis of strengths and weaknesses in singing. A NORAXON wireless EMG was used to measure the muscle activities of a female voice professor as she sang the notes F_3 (low pitch), F_4 (medium pitch) and F_5 (high pitch). The results showed a non-linear, but noteworthy and consistent increase in muscle activity, as the pitches became higher. They confirmed our hypothesis that EMG can be used as a quantitative assessment of singing and showed that there exists a reliable connection between the level of muscle activity and musical pitch. Most importantly, this study showed that EMG has the potential for better teaching method and could increase the reliability of talent searches in singing.*

Index Terms—*Maximal voluntary contraction, Muscle activity, singing pedagogy, Talent search*.

1. Introduction

Innate talent is essential in a voice career. In addition to well developed vocal, musical and phonetic ears, which are activities in the Central Nervous System, talent in singing refers to a physical ability to sing high pitched notes. Singing is partially powered by muscles, which have physiological limits that vary from person to person and is primarily determined by nature. It is generally, but not universally accepted that the variation in human muscle ability is caused by the existence of different muscle fibre types, which are genetically determined [2,3]. Training can manipulate the natural biological state only to a small degree, with slower gains near the ceiling of one's genetic potential [1]. The correct identification of innate physical talent is thus imperative, even under strict time constraints such as during auditions. Traditionally, talent searches have been done through subjective methods and are largely experience-based. The decisions about one's innate ability and their justifications are usually given in very vague terms, such as "beautiful" sounds and "good" control of dynamics. Consequently, there always remains some uncertainty. Many external conditions, such as illnesses, nervousness or impartial judgment may negatively affect the outcomes of an audition. Thus, a reliable objective method is desirable.

To the authors' best knowledge, no quantitative research currently exists that examines the biomechanics of singing. Given music as a human biocultural phenomenon (related to muscle activity and control of the Central Nervous System), and recent progress in bio-activity analysis technology (such electromyography (EMG) for exploring muscle action during any human activity and electroencephalogram (EEG) for detecting the electrical activity of the brain), it is time to use modern tools to provide supplemental and objective data that shows a student's biological capabilities, which is unaltered by temporary external conditions. Systematic, empirical inquiry into the biomechanics of singing holds the potential to inform and significantly facilitate talent searches by eliminating irrelevant influences and reporting innate physical talent as a number. Our study uses EMG to achieve this quantification of talent in singing.

Singing requires two muscles located at the abdomen, named Rectus Abdominis along with the other muscles (mainly the diaphragm and muscles between the ribs), to achieve the apogio (ital., a diaphragm tone support) and to support proper posture [4]. Previous studies have shown that the ability of the human body to maintain

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muscle activities is determined by the muscle intensity level and the duration of activity, ranging from 10 seconds at over 90% of the maximal muscle activity (physiological limit) to over 2 hours at 40% of the physiological limit [5]. One possible way of quantifying muscle intensity levels is EMG, which measures electrical activity associated with neural firings in musculature. It could be, therefore, an instrumental assessment of human potential related to musical pitch, length and loudness of tone, as well as control of vocal skills. One of our goals is to test this hypothesis.

In addition to talent search, this quantitative assessment of singing can be very useful in pedagogy. Long-standing traditions surrounding performance pedagogy have made it largely an arcane art. The primary instructional approach is based on an apprenticeship model whereby musical knowledge, skills, and attributes are passed from teacher to pupil. The product, that is the performance, defines and validates the success of the teaching and learning and the immediate end is often used to justify the pedagogical means [6]. Good training should result in better performance, which should also be accompanied by biological changes. Specifically, training should increase the biological efficiency of singing, thereby decreasing the amount of muscle activity required to sing. The extent of change depends on the effectiveness of the training received. Although different students respond to various teaching styles differently, one can identify generally successful pedagogy by comparing the change in EMG of different teaching styles.

The purpose of this study is to explore the use of EMG in quantitatively describing physiological and biomechanical phenomena associated with singing. The goals are to validate EMG as a quantitative tool for identifying singing potential and for reliable teaching evaluation. The method could also offer objective performance evaluation to voice professionals. This current research can be used to provide a framework for exploring these same issues in other performing arts.

2. *Method*

The current study uses electromyography to determine percent muscle usage. Electromyogram measures electrical activity associated with neural firings in musculature. A neural pulse train is transmitted by the muscle fibers associated with a desired movement and each neuron innervates several muscle fibers. The resulting raw EMG signal detected by surface electrodes is a summation over the ensemble of pulse trains associated with the muscle. The signal spectrum ranges from 0 to approximately 500 Hz. In the current study, eight-channel, wireless NORAXON (NORAXON U.S.A., Inc., Arizona, USA) EMG was used to determine selected muscle activity. NORAXON's hardware specifications provided raw signal recordings at a rate of 1080 Hz, with a band pass filter of 16-500 Hz, effectively minimizing environmental electrical noise.

In order to interpret EMG (a measurement of internal muscular activity) in a meaningful way, secondary processing of raw data must occur. A variety of EMG processing protocols exist and we chose the one most commonly found in the literature – enveloping [7,8,9]. The process involves full-wave rectification of raw EMG signals and low-pass filtering (Fig.1). We employed a Fast Fourier Transformation (FFT) low-pass filter of 6 Hz. Such filtering improves EMG sensitivity as a diagnostic tool by retaining dominant components of the signal while eliminating unstable high-frequency ones. The value of 6 Hz used in our study is a median of those found in the literature for light to normal activities. In our view this is appropriate for characterizing muscle activity during voice performance. Cut-off frequencies typically depend on muscle contraction rates as follows:

1. relative fast contraction - Parkinson's disease (15 Hz) [10] ,
2. normal activities such as gait (6-9 Hz) [9,11],
3. light lifting (3 Hz) [12],
4. posture control (Quiet stance 1.2 Hz) [13].

It must be noted that enveloping alone provides a *non-quantitative* way to assess neural muscle activity. In order to provide *quasi-quantification* and comparison between trials, normalization is needed. The normalization process expresses all EMG measurements as a percentage of a chosen reference value. Commonly used references include: 1) the maximum signal level during a trial, and 2) a Maximum Voluntary Contraction (MVC) determined in a separate trial under high-load conditions as a reference value. Using the first of these provides results of questionable quantitative utility as the "reference" may vary from trial to trial, and muscle capacity will likely be higher than the chosen reference. The second approach establishes the physiological limits of the muscle, a value that does not change from trial to trial. We use the latter to express load intensity as a percentage of the physiological limits of the individual. In the current study, MVC was determined using the average of maxima measured using three high-load trials. Figure 1 shows the complete procedure for processing EMG signals.

In the current study, EMG electrodes were positioned mid-muscle longitudinally on the left and right Rectus Abdominis. Wire leads to the electrodes were run under the clothing of subjects (t-shirts) to a preamplifier pack worn on the belt (weighing about 200 grams). Signals from the preamplifier were transmitted to the main amplifier. Subject wore a black stretch-material garment over top of her t-shirt, effectively eliminating the relative movement of the wires to the skin, yet providing for complete freedom of movement. The use of this kind of "wireless" system minimizes the laboratory-based constraints that normally occur with the use of "wired" EMG (where subjects' motor control patterns may be inadvertently altered due to the presence of umbilical wires between the measuring system and the subject).

The test protocol consisted of evaluating a common skill frequently asked for during auditions. The subject sang a F (tone) ten times, in groups of five, the first four of which lasted one second (brief period) each while the last one continued for four seconds (maintenance period). Three trials were conducted and data was examined for F_3, F_4, and F_5. This protocol permitted three different ranges—low (F_3), medium (F_4) and high (F_5)—to be evaluated, and resulted in capture times around 20 seconds in duration. One full-time, female voice professor participated in this study.

3. *Results*

Data was highly reproducible for all pitches. Figure 2 displays a typical EMG excursion for singing F_5. The EMG showed approximately the same peak intensity for all short (1 second) and long (4 seconds) F_5s, though the start of both brief (1 second) and maintenance (4 seconds) periods demonstrated lower EMG levels than their respective ends. The first note of the brief period always corresponded to the lowest EMG while the maximal EMG was found towards the end of the maintenance period. For this well-trained subject, singing F_5 reached, on average, 42% of her MVC with a standard deviation of 4%. The peak values ranged from 41% to 62% of MVC.

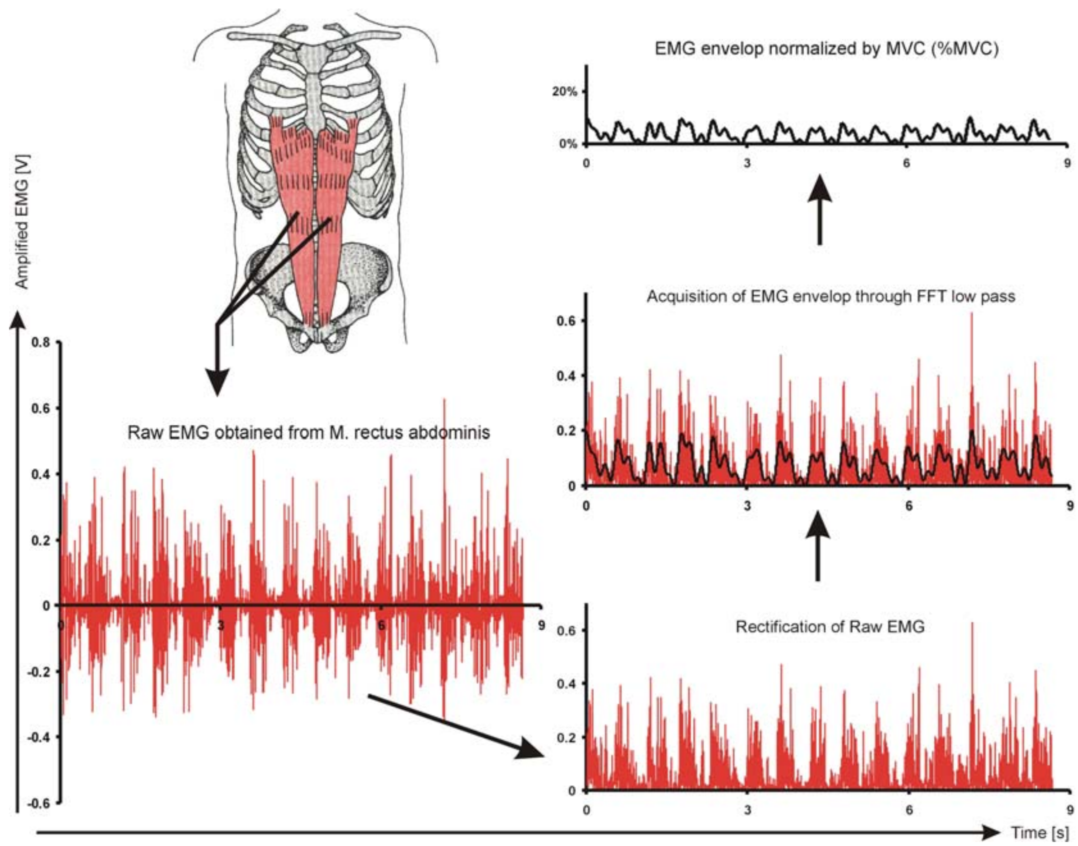

Figure 1. The process establishing enveloped and normalized EMG.

Figure 3 compares muscle intensity levels of Rectus Abdominis when singing F_3, F_4 and F_5. The muscles operated on an average of 10% MVC when singing the low pitch F_3 and 15%

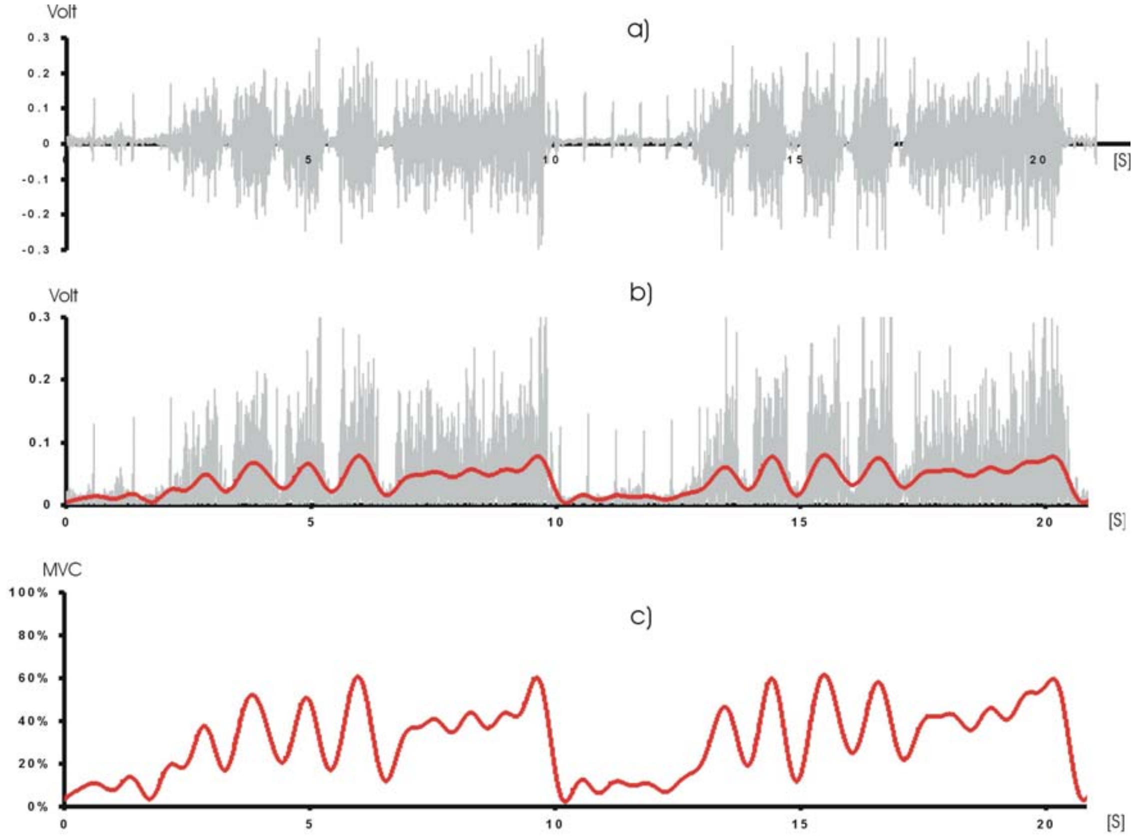

Figure 2. A typical EMG excursion of Rectus Abdominis during F5 singing. a) Raw EMG, b) EMG envelop, and c) Normalized EMG.

when singing the middle pitch F_4. Connecting these results to those found for F_5, a non-linear increase in percent of muscle usage can be seen—muscle activity increased at a greater rate than the pitch of the notes being sung.

For $F_{5,}$ the four-second maintenance period can be clearly distinguished from the one-second brief periods while no such distinctions can be made for F_3 and $F_{4.}$ In fact, from the muscle activities of the lower pitches, it is not even apparent the time at which a note is being sung. At the low pitch, the percent muscle usage ranges from 2% to 15% which is an intensity level that allows for hours of continuous work without fatigue. As the pitch increases, the range also expands—with higher maximal values observed. F_4 causes muscle activity between 3% MVC and 22% MVC, while F_5 returns values ranging from 2% to 61%. All three EMG had very small variations—the standard deviations were all below 5%.

4. Discussion

The results of this study confirmed our hypothesis that EMG can be used as a quantitative assessment of singing. They showed that there exists a reliable connection between the level of muscle activity and musical pitch. As such, we can speak of biological parameters (percentage of MVC) and musical properties (pitch) interchangeably. This numerification process of singing evaluation offers the advantage of converting a hitherto arcane art into a scientific procedure. We are not at all denying the importance of artistic expressions; we simply believe that vivid performance is based on solid technique, or basic skills. Given this, a quantitative evaluation of such skills will identify the basis of creating extraordinary music. Electromyography, therefore, has the potential to be a reliable way of demystifying the art of singing.

It should be noted that EMG is already an accepted daily evaluation tool in physical therapy and certain sports training [14]. Most recently, real time EMG has been used to adjust intensity levels of rehabilitation and sports training through bio-feedback [15]. This success can be partially attributed to the small and convenient size of the device (11cm×7cm×3cm) as well as its straightforward usage. Because the data collection apparatus obtains bio signals from the surface of the skin (surface EMG), it offers no intervention and negligible constraints on the subjects' motor control (singing) patterns, thus generating a realistic electromyogram.

We believe that EMG can be introduced into singing pedagogy with equal success. It can be used to facilitate learning as well as to offer objective evaluation of both training methods and student performance.

Motor control is generally learned in three phases—recognition, optimization and automation [16]. By allowing students to visualize the muscle activity of the teacher through EMG, the recognition process could be accelerated. Real time bio-feedback for the students will instantly identify improper motor control, allowing for immediate correction, which could then shorten the optimization process. It is well known that the first two phases are essential to obtaining the correct control patterns [17].

Due to genetic variations, singing ability varies from person to person. Everyone has a physiological limit, which is primarily determined by nature. Training can manipulate the natural biological state only to a small degree, with slower gains near the ceiling of one's genetic potential. This is known by exercise scientists as the ceiling of adaptation [1]. It is clear that innate talent is essential in the music industry.

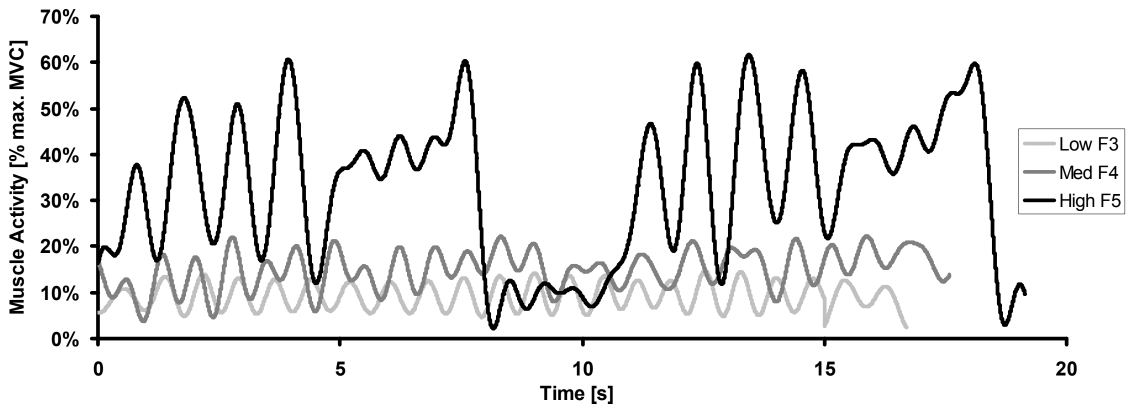

Figure 3. Comparison of muscle intensity levels during singings of different pitches (F3, F4 & F5).

Electromyo-graphy offers a scientific method for a reliable physical-talent search. For novices, it is conceivable how a subject using 70% MVC while singing F_5 has more physical potential than one using 90% MVC.

Many different styles exist in singing pedagogy. It is in the practitioners' best interests to identify the most effective approaches. To the authors' best knowledge, the area of quantitative research has yet to be introduced to singing. EMG has the potential to address this deficit through Pre- and Post-Training Analysis. In order to evaluate each teaching style, the following procedures could be followed.

Randomly assign subjects (students) to different groups, statistically ensuring equivalent bio initial conditions. Each group will receive one training method for the whole training season. The groups shall differ only in the teaching style; all other variables, such as length of training, should be identical. Prior to training, obtain the percentage of maximal voluntary contraction (MVC) required to sing a certain note for all subjects (pre-training measure-ment). Collect again the same EMG at the end of the training season (post-training measurement). Statistically significant differences among changes in the EMG of different groups will identify effective teaching methods.

On the other hand, this same evaluation can also provide students an objective assessment of their performance. Such an objective evaluation is very desirable because it eliminates subjectivity, which can be influenced by teacher-student relations as well as personal preferences.

One should note that, so far, this method can be interpreted only by a person educated in biomechanics, hardly by a singer. To address this, a software can be developed to automate the data interpretation and generate easily understood reports. For such a development, a multidisciplinary cooperation is necessary.

It should be noted that this research is only a case study. The authors understand that there are variations in singing techniques as well as natural variability from performer to performer. In order to justify and standardize this method, more trials and subjects are required to give statistical reliability. Future studies could concentrate on the influences of gender, age and race on singing. It has been established that such factors do indeed affect motor development and control [16]. Therefore, if we could establish databases based on these factors, we could provide more accurate evaluations and predictions of one's innate singing ability by comparing and contrasting the subject's EMG with the known EMGs of others with similar conditions.

5. CONCLUSION

This study suggests that electromyography can provide valuable objective information on singing evaluation, which may help better pedagogy and increase the reliability of talent search.

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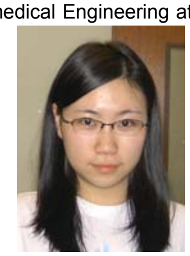

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Validation and Usability Analysis of Intelligent Systems: An Integrated Approach

Mosqueira-Rey, Eduardo; and Moret-Bonillo, Vicente

Abstract— V*alidation of intelligent systems is a complex matter due to the lack of standard references for complex domains. Moreover, the validation phase should be followed by a usability analysis for studying the quality of man-machine interaction. The VISNU (Validation of Intelligent Systems aNd Usability) tool has been designed to assist developers in the validation and usability analysis phases in intelligent system design. The validation module includes quantitative measures (such as pair tests, group tests and agreement ratios) and facilities for planning the entire process and for interpreting the final results. The usability module includes different types of usability analyses, namely, heuristic (based on the collaboration of experts), subjective (based on the collaboration of users) and empirical (based on objective data). One of the main goals of the system developers has been to integrate different evaluation methods to obtain information which could not otherwise be obtained.*

Index Terms—*Key words or phrases in the alphabetical order, separated by commas*

1. INTRODUCTION

Like all computer systems, intelligent systems require, as part of its development methodology, the inclusion of a process for analysing the functioning of the system [1]. This process is usually divided into different phases that analyse particular aspects of the system. Although these phases are designated by a range of well-known terms (verification, validation [2], usability analyses, etc), definitions tend to vary widely among authors, and despite efforts to standardise the terminology [3], the reality is that each author tends to use his/her own definitions. Below is a list of the most commonly used definitions [4][5]:

- *Verification*: the process that ensures that the system is structurally correct.
- *Validation*: the process that ensures that the system results are correct.
- *Usability analysis*: the process that tests aspects related to the human-computer interaction (HCI).
- *Utility analysis*: the process that tests the benefits of the system in the domain within which it will be used.
- *Evaluation*: the process of performing an overall analysis that includes the above-mentioned phases.

These phases generally follow a logical developmental sequence. However, contemporary iterative and spiral development methodologies execute these phases in several cycles, with gradual increases in range.

1.1 Verification and Validation

Verification is a 'white box' analysis of the system; in other words, the internal structure of the system is analysed in order to uncover possible errors or anomalies. Boehm [6] defined verification as the process of checking whether we are "building the product right".

An important verification limitation is the fact that this phase involves an internal analysis of the system, with the implication that systems with different structures need to be verified using different strategies. Thus the verification of intelligent systems is not quite the same as the verification of conventional systems; moreover, it is not quite the same to verify an intelligent system based on production rules and one based on Bayesian networks, to just cite one example. What's more, in many cases verification depends on the specific tool used for coding the system.

Validation, meanwhile, consists of a 'black box' analysis of the system; in other words, it is not the internal functioning of the system which is being tested, but rather the responses of the system to a specific set of inputs. Boehm [6] defined validation as the process of checking whether we are "building the right product" according with the previously stated definition of validation.

There is an important implication in the fact that the validation phase considers the system as a black box: the models, methods and tools designed to support this phase can be applied to any intelligent system, since there is no need to take into account the internal structure of the

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system or the tool used for its design. One of the first works containing an analysis of the validation phase was an article by O'Keefe et al. [7]. In this article, important questions in relation to validation were posed, for example: What do we evaluate? What data do we use for the validation? How do we evaluate? Who should be involved in the process? Further articles on the subject were subsequently published by O'Keefe and O'Leary [8] and by Gupta [9]. A description of the main verification and validation tools between the years 1985-1995 can be found in [10].

Of all the issues raised by validation, probably the most important question is in relation to the validation criterion. In other words, if validation treats the system as a black box and only analyses its outputs, then we require a criterion that will indicate whether these outputs are correct or otherwise. This poses no particular validation problems with conventional systems, given that it is a relatively simple matter to check whether an algorithm produces the expected results. However, for intelligent systems that model human knowledge, the identification of a validation criterion is more problematic. In practice, one of two approaches to validation are typically taken, defined according to the kind of criterion used:

- *Validation against the problem*: A standard reference exists that is used to test that the system results are correct.
- *Validation against the expert*: No standard reference exists and so system interpretations must be compared with those of human experts from the domain.

Validation against the problem is the more ideal approach; it generally relies on measures such as true/false positive/negative ratios, which are combined in graphs such as ROC curves (Receiver Operating Characteristic) [11].

Should this approach not be possible, then evaluation against the expert is the next best alternative. To avoid subjectivity in the validation process, it is recommended that several experts (not involved in the design of the system) be used. The ideal approach consists of a standard reference obtained by means of the experts reaching a consensus in their interpretations using a technique such as Delphi [12]. Nonetheless, the process of developing a consensus is both slow and costly, and so the normal procedure is for the experts to work individually. This has the advantage, however, of permitting an analysis of any inconsistencies that may arise in individual interpretations.

Another problem of validating an intelligent system against a group of experts is that the volume of information obtained is high, and this requires the use of statistical and multivariate analysis techniques to facilitate the interpretation.

1.2 Usability and Utility

Verification and validation have been performed in conjunction on so many occasions that they have jointly become known as 'V&V'. Nonetheless, more recently, usability and utility analyses have been attracting the interest of system developers, above all as a consequence of applications becoming accessible to individuals without computer knowledge, through networks such as the Internet and applications such as the World Wide Web [13][14].

Whereas verification and validation are concerned with system functioning, usability analyses endeavour to evaluate aspects that go beyond correctness of results and that involve the quality of the man-machine interaction. Utility analysis, on the other hand, rather than evaluating whether the system is usable, evaluates whether it can bring additional benefits to users. Although usability and utility are two distinct evaluation phases, in practice both are analysed jointly. Adelman and Riedel [4], for example, provide a questionnaire for a joint analysis of both phases.

There are many usability analysis techniques available, which various authors have classified in different ways. Preece [15], for example, classified usability analyses as analytic, expert, observational, survey and experimental. Another interesting work by Ivory and Hearst [16] includes a classification of usability analysis techniques and tools in terms of the four dimensions of method class, method type, automation type and effort level. The method class category (equivalent to Preece's classification) includes testing, inspection, inquiry, analytical modelling and simulation. In our research we have preferred the Adelman and Riedel classification, which identifies three types of techniques for analysing usability:

- *Heuristic*: These techniques are based on the opinions of usability experts, who analyse the system and determine strengths and weaknesses from an end-user perspective.
- *Subjetive*: These techniques are based on the opinions of the system users, who analyse operational prototypes and give their opinions on the usability of these prototypes.
- *Empirical*: These techniques, which are based on the actions of the system users, function on the basis of obtaining objective data on practical use of the system.

These techniques are not necessarily mutually exclusive; for example, one post-event protocol consists of a video recording of system-user interactions that is subsequently commented on by the user. Thus, an empirical element is filtered through a subjective interpretation provided by the user.

1.3 Aims

This paper describes the VISNU (Validation of Intelligent Systems aNd Usability) tool, designed specifically to assist in the development of validation and usability analyses for intelligent systems. The most important features of VISNU are as follows:

- It integrates different methods and approaches for evaluating intelligent systems in one product.
- It includes novel aspects such as the use of artificial intelligence techniques for the interpretation of results.
- It integrates the results of different analysis methods so as to obtain information that could not be obtained by results interpreted in isolation.

Verification aspects have been excluded simply to ensure that the tool can be applied to as many systems as possible, regardless of the knowledge representation paradigm used.

The paper is laid out as follows: section 2 describes the VISNU architecture and modules; section 3 shows some examples of the application of VISNU; and finally, sections 4 and 5, respectively, contain discussion and conclusions.

2. METHODS

VISNU's novel contribution lies in its integration of several evaluation techniques in a single tool and the possibilities it offers for the combined functioning of some of these techniques. Table 1 provides a summary of the different techniques implemented in VISNU, to be commented in more detail below.

The validation module is divided into three main parts: (1) planning: that establishes the main validation strategies, (2) application: that calculates a series of quantitative measures (pair measures, group measures and agreement ratios) for analysing the intelligent system results and (3) interpretation: that tries to elucidate whether the intelligent system is really behaving as an expert within its field of application.

As for usability three kinds of techniques are considered: (1) heuristic techniques: such as the creation of GOMS [17] (Goals, Operators, Methods and Selection rules) models or ergonomic checklists. (2) subjective measures: for obtaining the opinions of users, in the form of closed questionnaires that can be analysed using MAUT [18] (Multi-Attribute Utility Theory) or AHP [19] (Analytic Hierarchy Process). And, (3) empirical techniques: such as statistical analyses for log files, identification of hierarchical tasks from log files and the possibility for instantiating GOMS models from logs and comparing predictions *a priori* with results *a posteriori*.

TABLE 1. EVALUATION TOOLS INTEGRATED IN VISNU

Validation	Planning	• Planning of validation process
	Pair measures	• Agreement index • Within-one agreem. index • Kappa • Weighted kappa • Spearman's rho • Kendall's tau and tau b • Goodman-Kruskal gamma
	Group measures	• Williams index • Hierarchical cluster • Multidimensional scaling
	Ratios	• True/false positive/negative ratios • ROC curves • Jaccard coefficient
	Interpretation	• Heuristic interpretation of validation results
Usability	Heuristic	• GOMS models • Ergonomic checklists
	Subjective	• MAUT questionnaires • AHP questionnaires
	Empirical	• Log analysis • Task analysis • GOMS-log integration

2.1 VISNU architecture

The architecture of VISNU is based on object-oriented programming using design patterns [20]. The inclusion of these patterns makes the tool more flexible and extendable to future modifications, so the inclusion of new modules or the modification of existing modules does not affect the other modules in the system. The VISNU project is based on the following four clearly differentiated modules (Fig. 1):

- *gui*: this includes the code for implementing the main graphical user interface that supports the interfaces for the different modules.
- *util*: this contains the helper software for the other modules.
- *validation*: this includes the modules designed for carrying out the validation processes, among which the most important are: (1) *gui*: the validation module interface, (2) *planning*: the planning system, (3) *measures*: quantitative validation measures, and (4) *interpretation*: the interpretation system.
- *usability*: this includes the modules designed for carrying out the usability analysis proce-

dures, among which the most important are: (1) *maut*: that implements questionnaires that can be analysed using MAUT, (2) *ahp*: that implements questionnaires that can be analysed using AHP, (3) *logging*: that implements the GOMS analysis, log analysis and the GOMS-log integration.

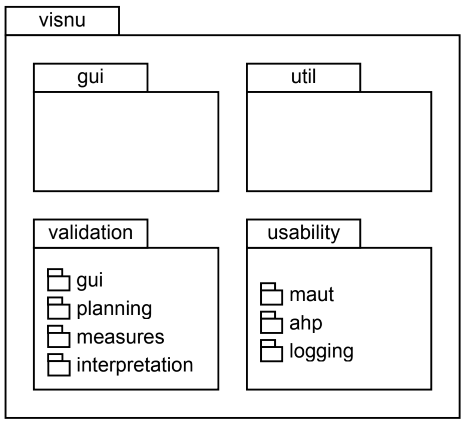

Fig. 1. VISNU modules.

The following sections will describe the validation and usability modules in more detail.

2.2 Validation module

The validation module in VISNU was developed on the basis of previous work performed by the authors on the validation tool SHIVA (System for Heuristic and Integrated Validation) [21]. This tool was designed according to a methodology that divided the process into three phases, namely, planning, application, and interpretation.

2.3 Planning

With a view to determining the most suitable validation strategies, the planning phase involves an analysis of the system characteristics, the application domain and the development phase.

Table 2 shows the criteria that are analysed in the validation planning process. For example, if the outputs of the system follow an ordinal scale, the most suitable approach is to weight the discrepancies according to importance (for example, in the symbolic processing of a given variable, a discrepancy between the categories 'very high' and 'slightly high' is not quite the same as between the categories 'very high' and 'very low'). Weighted kappa or the within-one agreement index are highly appropriate measures for taking discrepancies into account. Further details of the planning module are to be found in [21].

2.4 Application

The application phase applies the strategies identified in the planning phase by making quantitative measurements using test data. The procedure for calculating the different quantitative measures is depicted in Fig. 2.

Table 2. Criteria to be analysed in the planning phase

Subject	*Criteria to be analysed*
Application domain	● Critical domains ● Validation criteria ● End-user profile
System	● Division in sub-systems ● Uncertainty management ● Type of output variables ● Type of problem in hand ● Relationship with the environment
Development phase	● Initial phases ● Intermediate phases ● Final phases

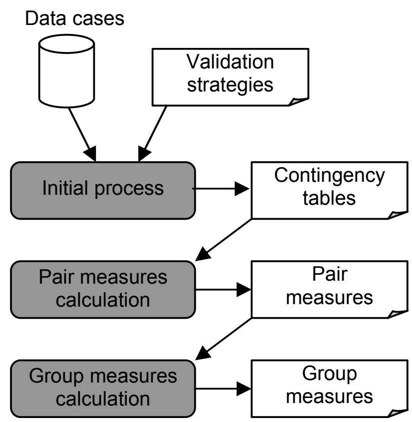

Fig. 2. Procedure for obtaining quantitative validation measures.

The first step is to analyse the existing test cases according to the validation strategies identified in the planning phase. This initial analysis permits us to construct contingency tables that correlate the interpretations of each of the possible pairs that can be formed between the experts that participate in the validation process (including the intelligent system).

Contingency tables will serve as the basis for the construction of pair measures, such as kappa or the agreement index, that provide an index that quantifies coincidences between the interpretations of two experts. Fig. 3 illustrates a contingency table and the pair tests obtained from it.

These pair measures can be used as input for the calculation of group measures, such as cluster analysis or MDS [22] (Multi-Dimensional Scaling) the objective of which is to analyse together the interpretations of the experts and to endeavour to find representation structures that permit an easier interpretation within the context of the validation. In Fig. 4 we can see a bubble graph that integrates clustering information with MDS information.

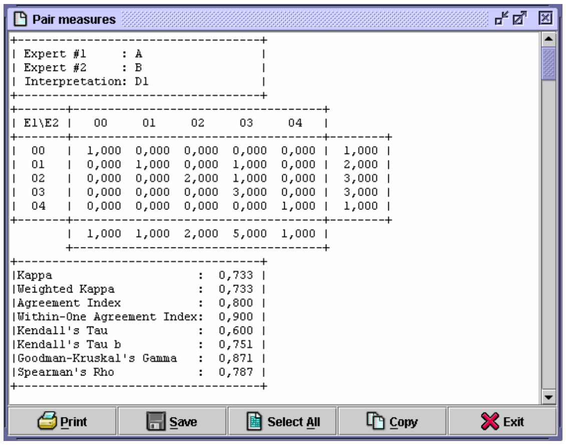

Fig. 3. Contingency table and pair tests.

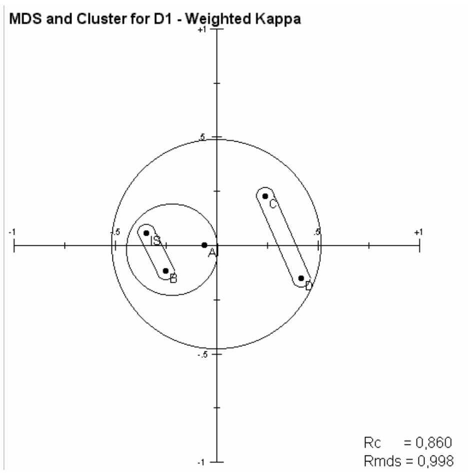

Fig. 4. Bubble graph integrating clusters and MDS information.

The advantage of VISNU is that it integrates all the validation techniques in a single module of the tool and the overall process can, therefore, be easily performed by the user. A description of these measurements can be found in [21].

2.5 Interpretation

The final phase, interpretation, involves an analysis of the results obtained in the application phase, with a view to testing whether the intelligent system genuinely behaves as yet another expert in the domain.

To facilitate the implementation of the interpretation phase it was decided to develop an expert system that would analyse the statistical results obtained in the application phase and draw conclusions on the performance of the intelligent system being validated.

The expert interpretation system is composed of two modules: an algorithmic module, based on the unprocessed data for the statistical measures, which produces output in the form of high-level information; and a heuristic module that processes this high-level information to obtain the final interpretation results [23]. The fact that the algorithmic module filters and processes the basic data to convert them into high-level information permits the rules of the heuristic module to be defined with an economy of expression.

2.6 Usability module

The VISNU usability module is designed to provide support for the different usability analysis techniques - heuristic, subjective and empirical (see Table 1). The following sections will briefly describe the different implemented techniques.

2.7 MAUT analysis

MAUT (Multi-Attribute Utility Theory) analysis is a formal subjective multi-criterion analysis technique, employed in usability environments to assess the utility of systems or alternatives that have more than one evaluable attribute [18]. The procedure for a MAUT analysis is as follows: (1) specification of the evaluation criteria and attributes; (2) weighting of these criteria and attributes according to their relative importance on a subjective manner, which leads to a subjective interpretation through an objective methodology; (3) testing how the system complies with each of the defined attributes; (4) creation of utility functions that will convert the above scores into utility measures; (5) integration of the utility values obtained for each attribute into a single measure; and (6) sensitivity analysis.

MAUT is very suitable for validating closed questionnaires (for which responses are restricted to a closed set of options). In our case the questions are used to obtain values for the attributes in our MAUT tree. Fig. 5 shows a hierarchical tree established to calculate the overall utility of a computer system [4]. It can be observed how the different attributes of the tree have been weighted according to their relative importance.

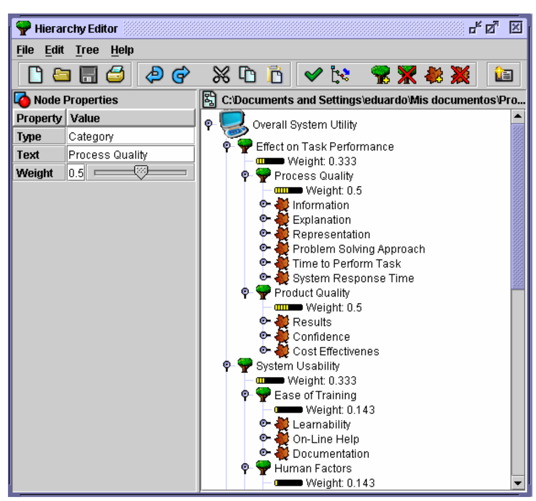

Fig. 5. MAUT criteria and attributes tree.

The questionnaire is developed by associating questions to attributes in the hierarchical MAUT tree. Because the questions do not need to have equivalent importance levels they can be weighted accordingly. The results of the evaluation of the responses to the questionnaire will give us an overall utility measure for the system being evaluated. The MAUT analysis can also be used to evaluate ergonomic checklists developed to perform a heuristic analysis of usability.

2.7 AHP analysis

One of the drawbacks to a MAUT analysis is that suitable utility functions need to be established for each study. To avoid the need to define such functions, another multi-criterion method can be used, namely, the AHP (Analytic Hierarchy Process). Developed by Saaty [19], AHP has an additional advantage over MAUT in that it permits a formal treatment of the inconsistencies that may appear in the analysis.

The drawback to AHP is that it is a comparative analysis, in other words, it is unable to reflect the utility of a single system in isolation, merely the utility of one system compared with an alternative system. AHP has other disadvantages, such as controversial ratio scales used to make the pair comparisons, or the rank reversal problem, which basically means that the AHP results may change if the number of alternatives changes.

The AHP module of VISNU can read criteria trees created for the MAUT questionnaires (Fig. 5) what allows to analyse the same problem using different tests (AHP or MAUT).

2.8 Log analysis

As we have seen in previous sections, one of the most common ways of measuring how a system is used is through an analysis of log files. In other words, the system non-intrusively records its interactions with the end-user, and these interactions are subsequently analysed to identify possible usability problems. The main drawback with the log method is that the data in the log files are generally low-level and lack context, which makes it difficult to identify the aims of the user when a log event was generated.

The log tool included in VISNU analyses log events and carries out an analysis of tasks, in other words, it identifies initial and final instants of the different tasks, errors and different device (mouse, keyboard, etc.) inputs that occur during the execution of a task. This task analysis permits the following information to be obtained:

- A statistical analysis of all the tasks executed including mean duration in time, number of instances, number of errors, etc. (Fig. 6).
- A hierarchical ordering of the tasks, with statistics about their composition (Fig. 7).
- The instantiation of a pre-existing GOMS model (described further in the next section).

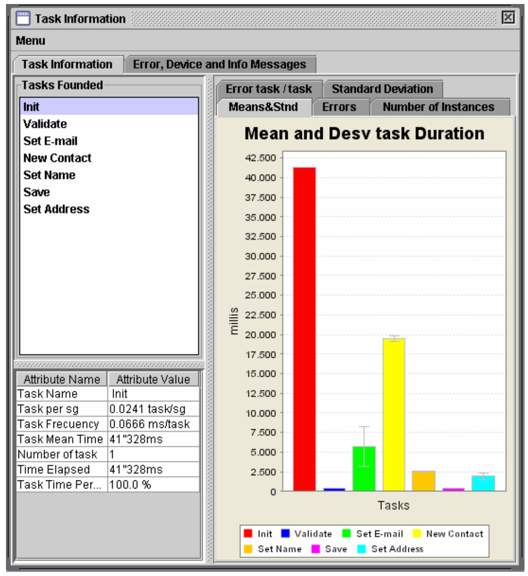

Fig. 6. Statistics for different tasks identified from the log file.

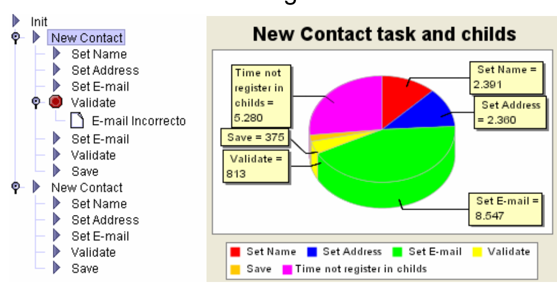

Fig. 7. Hierarchical structure for tasks identified from the log file and statistics about their composition.

2.9 GOMS-log integration

One of the novel aspects of VISNU is that it can not only make a GOMS-like heuristic analysis of usability, but can also integrate this information with the results of the empirical analysis performed by the log files. A GOMS analysis [17] is a formal analytical method for describing human-computer interaction in terms of Goals, Operators, Methods and Selection rules. The main advantage of a GOMS model is that it predicts times or sequences for the execution of commands even before the system is developed. For example, Fig. 8 shows a simple GOMS analysis for the tasks necessary to add a new contact to an agenda.

One of the main pitfalls of GOMS is that although it can be useful for the prediction of the normal user's behaviour, abnormal behaviour is not considered. Another pitfall is that GOMS models are useful for those occasions where one wishes to check minimization of the time needed to do a task, but less appropriate to check what tasks to do in the first place, how an application copes with different human behaviours, and how well the system is structured. Having that in mind GOMS can be considered as a valuable first step in the usability analysis.

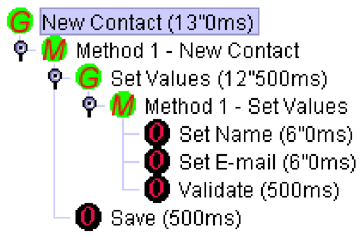

Fig. 8. GOMS model for creating a new contact.

VISNU not only permits to define GOMS models, it also permits such GOMS models to be instantiated with data from the log files. To do this, the log files need to be able to identify different tasks which must be allocated to different nodes in the GOMS tree (although this allocation does not need to be exhaustive, a more complete allocation will ensure a more accurate instantiation).

An example of an instantiation of the GOMS tree of Fig. 8 is depicted in Fig. 9. In this figure we can compare time predictions made a priori by the GOMS tree with real a posteriori results obtained in the actual use of the system. More information about GOMS and logging integration can be found in [24].

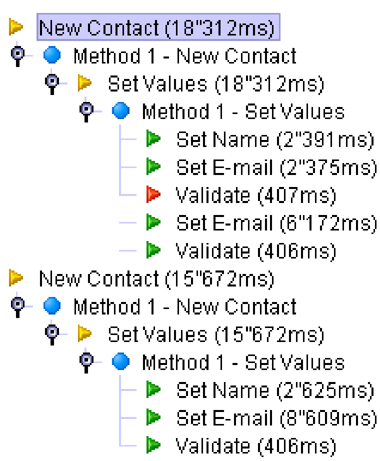

Fig. 9. GOMS model instantiated using a log file.

2.10 Module integration

The design aim for VISNU is a structure based on modules that are cohesive (abstractions that are logically related are grouped together) and loosely-coupled (dependence between modules is minimised). Fragmentation of a program in terms of individual components reduces complexity; it also creates a series of well-defined and well-documented frontiers within the program, which facilitates use and comprehension. Once the modules have been developed and tested separately, they are combined in a single application.

Another aim of the VISNU developers has been to make this tool available over the Internet by applying a rich-client philosophy. This philosophy has been adopted in view of the fact that web pages do not have the complexity necessary for the different modules of the application. Moreover, as the system is written in the Java programming language, it can be deployed via the Java Web Start platform, thus guaranteeing execution in any platform for which a Java virtual machine exists.

3. Application Examples of VISNU

Both the VISNU tool and its antecedent SHIVA have been used for validation and usability analysis for a number of intelligent systems developed in the Laboratory for Research and Development in Artificial Intelligence (LIDIA) of the University of A Coruña, Spain. These systems are: PATRICIA [25], NST-EXPERT [26], CAFE [27], MIDAS [28] and SAMOA [29].

PATRICIA is an intelligent monitoring system for patients in Intensive Care Units. Given the critical nature of the domain, validation was performed against 6 human experts using group measures. Space does not permit a detailed description of the results of the validation for each of the PATRICIA modules. However, what we can say is that the results were more than satisfactory for all modules, and that the validation process did permit to explain the discrepancies identified.

For example, in PATRICIA the result of the module for analysing the acid-base balance was used to establish the ventilatory therapy of the patient. In the validation, however, it was discovered that although PATRICIA did not agree with the experts in the interpretation of the acid-base balance, the system did coincide in the therapy based on this interpretation. This fact can be seen in Fig. 10, in the left the results of PATRICIA (G) showed that is clearly outside the main cluster of experts, but in the right PATRICIA is very near to the origin of co-ordinates meaning that is the expert whose interpretations are closest to the consensus.

This apparent contradiction was resolved by analysing the use of context (diseases, medication, etc.) in the evaluation of the patient. PATRICIA applied the context at the moment of analysing the diagnosis whereas the human experts used the context, not when indicating the diagnosis but when deciding the therapy. This example shows how an experienced intelligent system evaluator could take benefits from using VISNU. Complete validation results for PATRICIA can be consulted in [25].

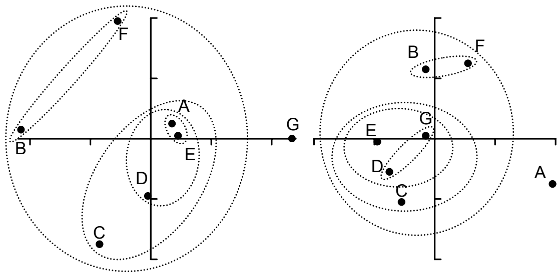

Fig. 10. Bubble graph showing the results of MDS and cluster analysis for acid-base balance interpretation (left) and ventilatory therapy (right) between human experts (A-F) and PATRICIA (G)

Other example of the application of VISNU is the SAMOA project, an intelligent monitoring system for patients with the Sleep Apnea Syndrome (SAS). In the near future, this system will be implemented as an element in daily clinical practice in the Sleep Unit of the Juan Canalejo Hospital of A Coruña. Given that the system will be used by staff with little computer knowledge, a usability analysis is needed.

The first part of the usability analysis was a heuristic evaluation based on an ergonomic checklist taken from the literature, but adapted to the particular features of our system. This ergonomic checklist was implemented using the MAUT module of VISNU. In this analysis two kinds of problems were detected related to the help system and the methods for preventing and diagnosing errors. The remaining categories obtained more than 65% of positive responses.

The second part of the analysis was carried out by issuing users with a questionnaire designed to evaluate performance aspects of the system, basically by indicating strengths and weaknesses as well as possible improvements to the system. The questionnaire had 101 questions organised into three main categories, as follows: task performance, system usability and system fit. The results of the questions, evaluated using the MAUT analysis, showed an average score of 4.08 (of the maximum of 5). The poorest results were in the areas of flexibility, user control, on-line help and documentation, and system adaptation to the user profile.

Finally, a preliminary empirical evaluation corroborated the above results in regard to deficiencies in the help function, given that the user has not used this function. A more complete description of the usability analysis of SAMOA can be consulted in [29].

As a final comment we can say that, in validation and analysing the usability of the previously mentioned systems, the VISNU tool has demonstrated to be both useful and accurate. However, as far as the own VISNU usability is concerned, only its actual use will conclusively demonstrate the validity of the followed approach. It is expected that, when the tool will be freely available in Internet, there could be obtained new experiences from other research groups.

4. Discussion

Evaluation is a crucial phase within the development cycle for any computerised system. This is even truer of intelligent systems that model human expert knowledge. In view of this fact, a great deal of effort has been invested in automating the different evaluation phases. Nonetheless, in our opinion the success of these tools can be considered relative, due to the fact that no single ideal method or tool exists that is capable of implementing the different evaluation phases. What does exist is a range of methods that are particularly indicated to evaluate specific aspects of a system. Combined use of these methods may provide the desired results.

This was precisely the philosophy underlying the development of VISNU, which integrates different evaluation techniques in a single tool and thereby provides the following benefits:

- All the evaluation tools are accessible through the same interface and are distributed together. The consistency of the interface for the different modules (icons, structure, etc.) has been maintained, thereby facilitating the learning process.
- Integration of the different tools in a single system means that it is a simple matter to use the outputs of one module as the inputs for another; moreover, this can be done automatically. Pair measures, for example, can be calculated automatically when a group measure such as cluster analysis is selected.
- In some cases it is even possible to integrate the results for the different methods in a single structure; for example, bubble graphs integrate the cluster and MDS results; and GOMS models can be instantiated from log files.
- Some of the methods – such as the group and pair measures for validation – include facilities for interpreting results using an expert interpretation system. The knowledge in this system is the fruit of the accumulated system validation experience of a range of knowledge engineers.

The use of VISNU in the validation and

usability analysis of real systems permits to develop a field validation of the own system. This field-testing revealed a number of interesting aspects of the system; in particular, application of our validation methods – despite the treatment of the system as a black box – not only allowed the performance of the intelligent system to be compared with that of human experts, but also permitted it to acquire new knowledge and/or refine existing knowledge.

5. CONCLUSIONS

The main aim underlying the development of VISNU was to integrate different evaluation methods in a single tool so as to benefit from the advantages of executing various evaluation methods together.

Validation tools can be applied to any intelligent system, given that they are independent of the underlying architecture of the system. Usability analysis tools can be applied to any computerised system since they involve no specific premises.

It is also important to point out that the validation and usability analysis phases should be integrated in a natural way in the software development process. Intelligent systems are software products, and so the experience acquired by software engineers can also be applied to knowledge engineering. Nonetheless, the distinctive features of these systems and of their application domains would indicate that in terms of development and evaluation methodologies, these systems differ fundamentally from each other within the software engineering field, and for that reason specific evaluation techniques are required.

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Telemedicine intelligent learning. Ontology for agent technology

Ferrer-Roca, A. O.; Figueredo, K.; Franco, A.; and Cárdenas, B.

Abstract— ***Telemedicine (TM) is an ever-evolving multidisciplinary subject where knowledge is acquired by continuous training rather than as part of a curriculum. The current challenge is to create an intelligent tool that delivers personalized training to professionals with different backgrounds, making use of scientific innovations from any source, even the Internet.***

We present an innovative metadata packaging and rule-building tool to achieve an adaptive retrieval system that may draw on all available resources. For this purpose we used vocabulary and ontologies founded on the telemedicine body of knowledge (TM-BoK) hierarchy and Medical Sub-headings (MeSH).

The packaging tool creates a modified XML-manifest that contains a Navigable Knowledge Map and a separate Rule-extension executed by Agents during the process of navigation. Agent systems also handle personalization, selecting packages by reading metadata tags. The result is an adaptive and adaptable TM knowledge delivery tool used by the students to reduce the time on searching information.

Index Terms— ***E-Learning, Ontologies, Standardization, Telemedicine.***

1. INTRODUCTION

TELEMEDICINE (TM) is a multidisciplinary field undergoing permanent evolution as it adapts to modern trends and innovations. Professionals with very different educational backgrounds (e.g. doctors, engineers, computer scientists, etc.) use it. Its training becomes a continuous process not acquired as part of a curriculum. Furthermore, it is difficult to find experts in every key subject. In these circumstances, it is a challenge to build an intelligent tool that provides personalized distance training with up-to-date information from any source, including the Internet.

Until now, medical information retrieval has been based on keyword matches of resource descriptions or metadata. Thus syntax and semantics, used to tag contents, have been incorporated into professional indexes. Those specific taxonomies or vocabularies to describe contents, such as Medical Sub Headings (MeSH) [1], provide a certain level of standardization.

Nowadays an effective search tool in Medicine will require a standardized content, preferably with metadata headings using eXtensive Markup Language (XML), accepted taxonomies, and MeSH vocabulary.

In addition, for teaching/training purposes some means are needed to handle educational content and user profiles (e.g. IEEE-Learning Object Metadata (LOM) paradigm [2], and IMS-Learning Information Profile (LIP)[3]) incorporated into the SCORM (Sharable content object reference model)[1] standard. It allows re-usability, interoperativity and extensibility. Its Content aggregation model and the Run-time environment specifications aggregate and display the same pool of learning objects in different orders or with different views.

Further improvements include an intelligent Learning Management System (LMS) able to deliver *adaptive* and *adaptable* data.

Interactive-adaptabliliy is the goal of DILE (Distributed Intelligent Learning environment) based on a Multiagent Technology with JADE (Java Agent Development Framework) [4]. This architecture implements an agent framework in order to set rule-building strategies for learning delivery actions; it takes into consideration Student Cognitive State, Teaching strategies and Knowledge acquisition assessment.

Interactive-adaptive data delivery implies a step further, since it represents a run-time learning delivery strategy based on detected skill management during the e-learning time [5]. In this case the platform dynamically re-adapts, exchanges, re-uses and shares learning objects (assets) according to user feedback, thus optimising skill acquisition.

To integrate these and future innovations the IMS organization [3] describes Learning Objects using XML capable of being understood by most e-learning tools.

The present paper presents a tool capable of managing students' interests and skills applied to TM e-learning. The objective was to build and test an intelligent tool capable of handling specific TM ontologies and at the same time electronically deliver personalized TM content depending on user knowledge and learning process.

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2. DESIGN

Our starting point was the IST-1999-12503-Knowledge on Demand (KOD) project[2]. Based on Agent technology, it builds an e-learning tool with the following properties: automation, adaptability,

[1] www.adlnet.org

[2] http://sharon.cselt.it/projects/jade/whoIsUsing/KODAgentsandeLearning.doc

intelligent management and re-usable learning objects.

2.1 System Description- TM Agent architecture.

We modified the above-mentioned e-learning system, specifically for telemedicine knowledge delivery. In this paper we detail the TM modifications. The final system, adjusted to current standards [2-5] contains *Authoring Components* ready to interact with a *Multi-Agent System* compliant with the Foundation for Intelligent Agents (FIPA) [6]. See **Figure 1**.

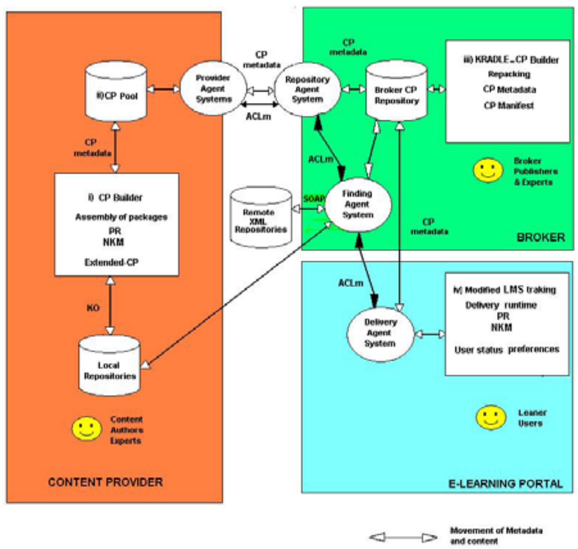


Figure 1. KOD system Description. Interaction between *Authoring components* and *Multi-Agent system*.

ACL= Agent Communication Language; AS= Agent System; CP= Content Package; KO= Knowledge Object; KRADLE= KOD Reusable Adaptive Learning Content Exchange; LMS= Learning management system; NKM= Navigable Knowledge Map; PR= Prescriptive rules; SOAP= Simple Object Access Protocol.

The *Authoring Components* are: i- a Content Package builder, ii-a Package Pool, iii-a KOD Reusable ADaptive LEarning Content Exchange Broker (KRADLE), iv- a Learning Environment, and v- an Educational Metadata Editor Manager.

i- The Content Package builder packs the information into an "extended" IMS-CP[3] standard. **Figure 2** shows the *knowledge rules* and *navigable knowledge map* extensions. Rules are packaged separately in order to be re-used. The knowledge map is a domain map representation (see below II.B.3)) built with items connected by attributes, concepts and available resources.

ii- The Package Pool collects and publishes packages and is able to detect new packages using Agents.

iii- The KRADLE is the broker of the remote repository of packaged metadata, whose Content Package Manifest is available for Agent interaction.

iv- The Learning Environment is the vertical learning portal for publishing, accessed via WWW. It includes a "modified" Learning Management System (LMS) that keeps learner performance and profile updated for Agent handling together with the usual LMS activities. These are student registration, sequencing instructions, content administration, assignment and recording performance, collection and data management.

v- The Educational Metadata Editor Manager is a tool to define, generate, export, and validate extra metadata. This is a Java applet editor suitable for modifying the document where the XML tag definitions are stored (Document Type Definition -DTD).

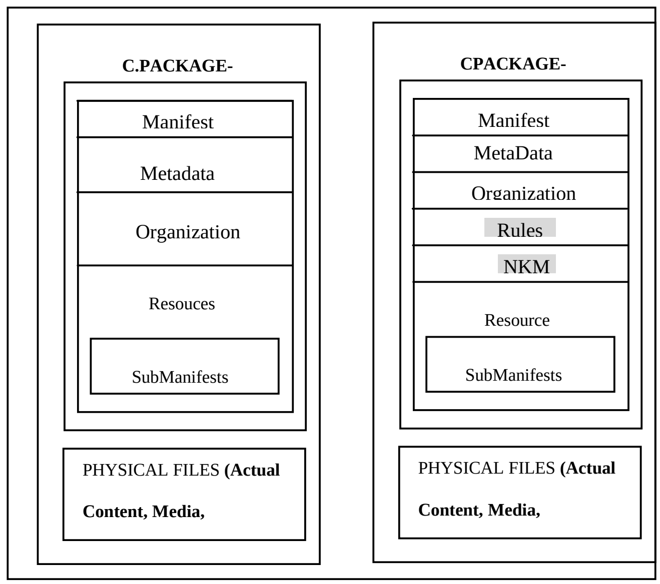


Figure. 2.- XML Content Package structure. The standard IMS CP on the left, versus IMS KOD CP on the right.

NKM = Navigable Knowledge Map

With respect to the *Multi-agent System* (**Figure 1**), messages between Agents are passed via Agent Communication Language (ACL) in *custom ontologies* (see below II.B.3. Managing attributes and enhanced data) based on adaptation rules, ontology, language and content. The Agent Architecture contains three functional layers: publication, brokerage and delivery. Each layer has agent systems as listed below; agents are named in brackets.

1. Knowledge Package publication layer. This has a Provider Agent System (Knowledge Package Publication monitor; Publisher Contact agent)
2. Knowledge package broker: 2.1. Repository Agent System, responsible for receiving and

[3] According to the IMS-CP (Instructional Management System-Content Packager) specifications of 2001, the learning packages are collections of different "organizations", each one including a number of "items" (learning paths); every item refers to one resource, which can include a number of learning objects.

managing incoming packages. (Knowledge Package receiver, Upstream Informer, ACT-ACL translator); 2.2 Finding agent systems. (Broker Package Finding, SOAP[4] Client Agent),

3. Knowledge package delivery layer, which is the e-learning service provider containing a Delivery agent system (e-Learning Service Provider Package Finder agent)

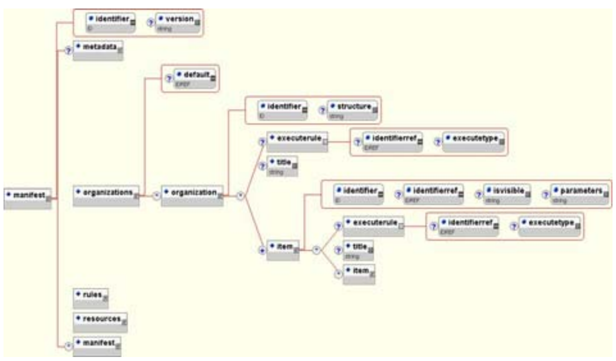
Except for the SOAP Client agent, none of the above can be duplicated in a platform

2.2 TM System Design

The system is designed to meet telemedicine learning demands and individual user requirements. It consists of:

1) An *Extended-Content Package:* Composed of TM knowledge learning objects packed in XML and tagged with metadata (e.g. IMS-LOM metadata). In addition to this, several navigation descriptions are included such as the *Table of Contents*, *Prescriptive Rules or Knowledge Maps* (see **Fig 3**).

Figure 3(a). - IMS-CP version 1.1 with the Prescriptive rule extension. Rules and execute rule.



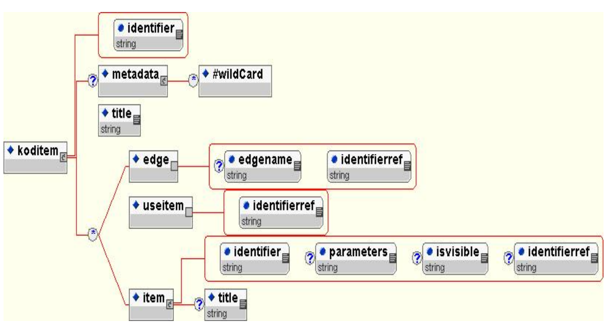


Figure 3(b). - Extended IMS-CP for the Navigable Knowledge Map

Figure 3(a&b)- The extended content package. The default Table of Contents (TOC) hierarchy is extended into three levels allowing user adaptive navigation through telemedicine items. These levels are:

1. Conditional branching (ADL-SCORM[1]) with Boolean conditions on lesson status.

2. Prescriptive sequencing Rules that control content activation based on the Learning Management System (LMS) tracking, taking into account user status and/or preferences. (See **Table III**).

3. Knowledge maps capable of changing the domain organizational views, depending on the Prescriptive Rules.

2) An ontology adapted to Telemedicine: For this learning environment we established specific vocabularies and domain ontologies capable of being used by metadata handling Agents.

a) Telemedicine classification: This contains categories whose entities are assigned according to one or more established criteria. There are twelve main categories in the Telemedicine Body of Knowledge (TM-BoK) [7]: *[1]* History of Telemedicine, *[2]* Minimal Technical Requirements, *[3]* Main Telemedicine Applications, *[4]* Basic Knowledge of Multimedia Communications, *[5]* Quality Control and Quality Assurance, *[6]* Internet in Telemedicine, *[7]* Distant Training Tele-Working and Tele-Teaching, *[8]* Data Security and Privacy, *[9]* Liability and Legal Aspects, *[10]* Economics and Management in Telemedicine, *[11]* Social Aspects and Technology Transfer, and *[12]* Emerging Issues.

The less common/significant entities are included in "other categories" and cover: *[i]* Standardization Bodies, *[ii]* Statistics, *[iii]* Colour Theory, *[iv]* Networking & TCP/IP[5], and *[v]* Informed Consent.

b) Coding schemes: The code-dependent hierarchy structures the major categories content into subheadings. For example, the Major Category-*[3]* entitled “Main Telemedicine Applications”, has the following subheadings: *[3.1]* Tele-radiology, *[3.2]* Tele-pathology, *[3.3]* Tele-cardiology, *[3.4]* Tele-home Care, *[3.5]* Tele-oncology, *[3.6]* Tele-surgery, *[3.7]* Tele-psychiatry, *[3.8]* Tele-dermatology, *[3.9]* Primary Care, and *[3.10]* Phone medicine.

c) Medical sub-heading for indexing medical procedures: Considering that TM is a medical subject, Medical SubHeading (MeSH) qualifiers can be used to refer to headings when applied to specific medical delivery procedures.

3) Managing Attributes and Enhanced Data: The extended content package (**Fig 2**) selects vocabularies twice; once for the metadata fields and once again for the Data Model and Navigation Knowledge Map.

Metadata fields are associated with the provided vocabulary including TM (**Table I**). In the case of the Data Model (**Table II**) and Navigation Knowledge Map, the *domain* is selected first, because it determines the specific vocabulary. In our case MeSH and TM domains were chosen, meaning: main categories II.B.2.a) supplemented with II.B.2.b.) and II.B.2.c.). Nevertheless, in some specific main categories different

[4] SOAP= Simple Object Access Protocol

[5] TCP/IP= Transmission control protocol/ Internet Protocol

vocabularies are required (i.e. *[9]* Liability and legal aspects require a Legal domain vocabulary)

Table I- Metadata vocabularies Association

Language	English / Spanish
Key-words	TM-BoK ; MeSH
Version	No vocabulary
Status	Lifecycle.status
Format	Mpeg/doc/html/ppt/pdf/xls
Learning resource type	Exercise/figure/table/problem/questionnaire/index/exam/test/simulation/graph/narrativetect/selfassess/diagram/slide/experiment/URL
Interactivity level	
Semantic density	
IntendedEndUserRole	Doctor/nurse/managerial/technical
Difficulty	Veryeasy/easy/medium/difficult/verydifficult
Context	Univ1cycle/Univ2cycle/Univ3cycle/ContEd/CovT
Relation.kind	Ispartof/isversionof/isformat/isreferencedby/haspart/hasformat/isbasedon
CopyrightAndOtherRestrictions	Yes/no
Subject	MeSH; Telemedicine; Legal; etc…

In the TM-BoK ontology, the attribute values or qualifiers of the main categories (i.e. nodes) are capable of building the dependency maps specific to the TM learning system. This would not be possible if MeSH qualifiers were chosen since they are not adapted to telemedicine categories and subcategories. This is regardless of the fact that both TM-BoK and MeSH hierarchies allow broader (parents or ancestors and siblings) and narrower (children or successors) concept relationships; and, that within a given hierarchy, a single concept may appear either as a narrower one or as more-than-one broader concept, thus being capable of creating dependencies and Knowledge Maps.

Table II- KOD Data Model for learner profile characteristics according to LIP model

KOD Data Model	Learners Characteristics
Kod.learner.demopersonal.language	Language
Kod.learner.ld.learnstyle	Learning Style (ILS-Index learning stile Felder & Silberman)[6]
Kod.learner.objective.[]	Goal (MeSH vocabulary)
Kod.learner.objective.[goal].interest_level	Competency
Kod.learner.objective.[goal].classification	Interest

In **Fig. 4** the Tele-radiology knowledge map *[3.1]* is shown to contain: Basic parts *[3.1.1]*[7] as well as Fundamental nodes (The term fundamental refers to main categories in the TM-BoK).

Defined *custom ontologies* allow complex data structures to pass among agents within Agent Communication Language messages. Our ontology implementation for communication purposes was deliberately simplistic. It was basically a rule container since attributes were considered beyond its scope particularly because actions are not read in the ontology but implemented through the behaviour of agents.

Adaptive package delivery was under the control of the *modified*-LMS, which was capable of interacting with agents (delivery agents) and of executing the run-time rules encoded in the Content Packages. The modified-LMS was also responsible for storing and checking user profiles and complementary information such as: elements already visited, performed rules and updated user knowledge. All the above is essential for personalized adaptive delivery.

3. *Application Deployment-TM demonstrator*

Two innovations have been implemented: A) Personalization and B) Re-using.

3.1 Personalization

This starts with the system *dimension* followed by prescriptive or adaptation rules to deliver customized contents.
The dimension definition enables the system to select *determinants* or parameters that help to decide whether the content (constituent) must be presented to a particular user. The *constituents* are divided into learning paths (collections of learning assets) and learning assets.

The dimension of the TM demonstrator takes into account user backgrounds, learning styles and goals:

- **Individuals**: The TM introductory courses reach a wide range of professionals, who were classified into three main groups: Medical Informatics Experts, Health Care Personnel, and Managerial people. The main determinant for the first group was technical issues, for the second medical items, and for managers economic and legal aspects.
- **Learning styles**: Regarding the format of available documents, half of the material had optional (textual or visual) presentation formats.
- **Topics**: Telemedicine being a new discipline, most material is *introductory* with a reduced number of *advanced* items. For that reason, we rejected so-called "dimension-levels", because no critical mass of contents is to be located in the advanced content set, in this initial demonstrator.

Table III shows a pseudo-code example of an "*adaptation rule*". When a particular user meets both conditions (being a doctor and interested in visual material), then the element addressed in the "table of contents" with the number 234 - corresponding to medicalvisualpresentation.ppt item- will be activated. In **Figure 5b** the final result is displayed.

[6] Learning and Teaching Styles in College Science Education (http://www2.ncsu.edu/unity/lockers/users/f/felder/public/Papers/Secondtier.html)

[7] *[3.1.1.1.]* Communications, *[3.1.1.2.]* Display systems, *[3.1.1.3.]* Image acquisition & management, and *[3.1.1.4.]* Interpretation

Table III- Pseudo-code of a prescriptive/ adaptation rule that controls content activation to deliver customized content.

Initialise an element as "disable".
IF determinant=true THEN constituent=enable, AND
IF (kod.user.occupation=medical AND kod.user.learningstyle=visual) THEN (kod.behavior.seqnav(man1_ToC_234_(medicalvisualpresentation.ppt)=enable)"

3.2 Re-Using

The authoring tool imports raw learning assets located anywhere (e.g. Internet) into the Resource-window (**Fig 5**). Once in the Knowledge-Object-window of the application, they are re-packed, re-used or modified according to the adaptive Knowledge Rules. As a result of the number of permutations (n-objects per j-dimensions), learning data delivery become individually adapted and highly personalized.

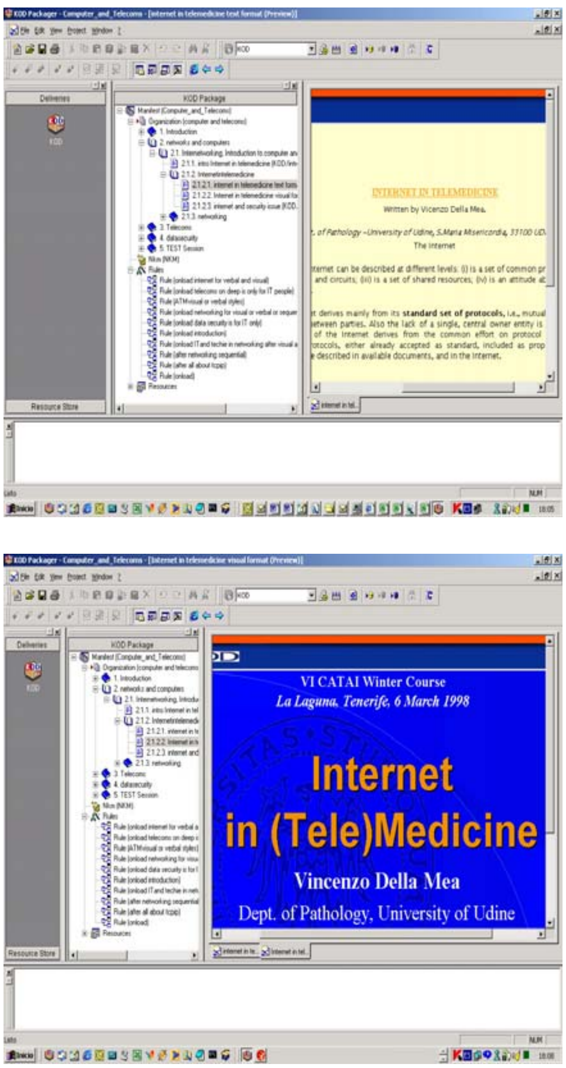


Figure. 5. – Knowledge personalization according to learning style.(a) textual; (b) visual.

The personalized packaged course (re-packable in each session or by the author) is just an aggregation, in the Knowledge Object window, of raw assets.

The system is permanently updated. For that purpose the "user-Agent" (who identifies each learner) of the Finding agent system (see **Fig 1**), looks into the available repositories for any material or complete package suiting user demands. Besides, it communicates with other agents in order to search in different repositories, including the Internet. The returned packages can be incorporated interactively into the course.

4. SYSTEM VALIDATION

For system validation a TM course integrated by a number of packages (cluster of contents organized by subject, topic, taxonomy…) to teach tele-radiology were build (**Figure 6**).

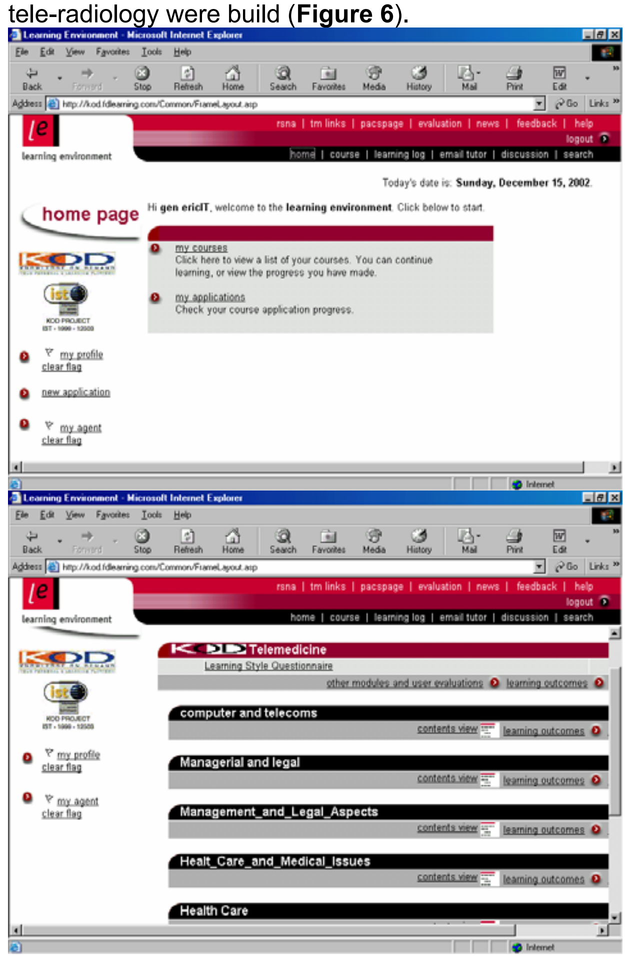


Figure 6. User portal interface for Telemedicine training. (a) Entrance to the portal. (b) Learning session for the specific student.

After checking student profile, the system decides which of those contents are suitable. The purpose is to deliver to each learner category exclusively the required information that fits his interest (doctors/ engineers/ managerial), learning style (visual or verbal) and goal (teleradiology/ quality control).
The adaptive course and package builder was provided to 96 students and 33 teachers. Their opinions were evaluated using questionnaires

(**Table IV & V**).

Table IV. User interest-difficulties to Telemedicine students.

1.	**How did you find the Tele-radiology learning usability?**
2.	**In your opinion the Telemedicine application and learning assets are…**
3.	**Has learning and time searching for contents improved?.**
4.	**Was tool familiarization time short and adequate?**
5.	**Were you able to track and bookmark your progress?.**
6.	**How did you find the telemedicine demonstrator?**
7.	**What is your opinion of the course building packager?**
8.	**Was the package builder easy to use:**
9.	**Is it easy to built a Telemedicine course?**
10.	**Is the TM demonstrator effective for learning:**

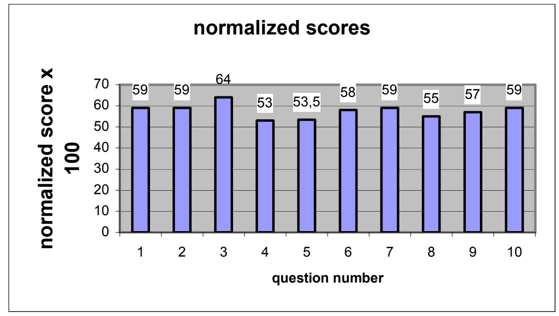
Table V. Teachers to analyse the authoring tool.

1.	**Opinion on Authoring usability?**
2.	**Opinion on Functionality for learners**
3.	**Opinion on the capability to create adaptive learning material.**
4.	**Opinion of the terminology used in the author interface**
5.	**Opinion on completeness of questions and test capabilities of the system?**
6.	**Opinion on the use of resources.**
7.	**Is the tool easier or as good as other e-learning tool?**
8.	**Is the Telemedicine demonstrator an effective learning tool?**
9.	**Opinion of the author user interface.**
10.	**Are steps to build a Telemedicine course simple enough?**
11.	**Is the terminology of the interface adequate?**
12.	**Does it support all expected functionalities for authors, publishers and brokers?**
13.	**Is the time spending to get acquainted with the use of the software reasonable?**
14.	**Do you consider that the test capabilities in the current version are sufficient?**
15.	**Opinion on the Rules interface?**

Answers were weighted from 0 to 3, with 3 being the maximum positive evaluation and 0 a negative or "do not know" answer . The global score was obtained summing the weight of each answer. The result was normalized dividing it by the maximum weighted score per answer (3x96=288 for students and 3x33=99 for the teachers).

Students of Telemedicine (University optional subject), evaluating the course, gave the results seen in **Figure 7a**. The average normalized weighted value was 57.65 per 100 with a standard deviation of 3.23. The best score was for time reduction in learning TM or searching for updated information (student question 3). The lowest score (53) was the time spent in becoming familiar with the tool.

Teachers were professionals familiar or not with e-learning tools. Results (**Figure 7b**) showed a 53.3% average weighted score with 10.03 standard deviation. The best score was for the capability to build adaptive courses (score 68; teacher question 3) followed by user interface, learner functionality (61) or rule-interface (60). The lower scores were for test-building facilities incorporated in the tool (33) and the time required to learn its use (38). A medium score (51) was given to the simplicity of building Telemedicine courses.



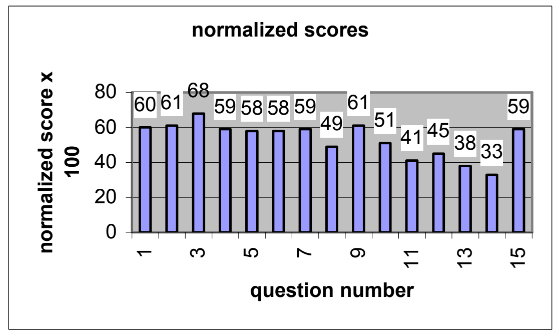


Figure 7. 7A-Students´ normalized score evaluation of the Tele-radiology course. 7B-Teachers´ normalized score evaluation of the Telemedicine authoring system.

5. DISCUSSION

The present TM Open and Distance Learning structure based on agent technology proved capable of personalized data retrieval according to user profile and goals. For that purpose we developed local and remote XML repositories, tagged with TM metadata vocabulary following TM ontology capable of being used by metadata handling Agents.

As shown in the design and deployment section this results in a multi-role personalised learning platform with a modular architecture that uses collaborative software Agents capable of reading the information located in the *modified*-XML-Manifest. Other Agents are devoted to representing the various user categories and to gather knowledge about a particular learner's profile, in order to adapt the delivery to this profile.

The platform proved to be very efficient in personalization issues, because it created only one package able to handle *n* objects per *j* dimensions, displaying only the suitable material and allowing re-use/re-pack learning objects. One of the major drawbacks was that it required tedious metadata filling sessions. The reason was that the tool does not contain automatic generation of metadata derived from relevant ontologies and resource description formats [8]; nor does it contain editing tools to add structured metadata, such as the eXtensible Authoring and

Publishing (XAP) Adobe metadata initiative for PDF formats.

Being a distributed platform for continuous learning it aims at using the Internet as an effective learning environment. Although medical researchers are often reluctant to trust Internet information mainly because it does not fulfil long-established verification criteria, the number of *on-line* Medical and Biology journals is increasing. Furthermore the availability of new techniques, lead us to consider the Internet as a future source of updated medical information. On the Internet, scientific papers can use handles [9] describing the physical location of the file (Universal Resource Names (URN) as part of the Universal Resource Identifiers) facilitating the search tasks. Moreover, the National Library of Medicine supported the Internet Engineering Task Force (IETF), in designing a quasi-permanent naming of web-based information objects. The Archival Resource Key draft entitled *The ARK Persistent Identifier Scheme* [10] defines three ARK services to access: i) the object, ii) the description of the object (metadata), and iii) the commitment description, made by the Name Mapping Authority (NMA) regarding the persistence of the object (policy).

Semantic webs are going in similar direction using: i) software Agents able to negotiate and collect information, ii) Markup Languages to tag many types of information and iii) Knowledge Systems enabling machines to read web pages and determine their reliability [5].

In the medical field, Internet discovery tool innovations go from web Ontology Agents capable of retrieving information in an intelligent manner [11] to Medical Core Metadata (MCM) standardizing attributes and enhanced data to be used by agents [12]. Finally, to support free text queries, terms should be compared with established vocabularies; the free web resource HSTAT (Health Services/Technology Assessment Text) [13] accesses full-text document title, checking users spelling queries by means of software Agents based on Unified Medical Language System (UMLS) meta-thesaurus.

The success of any of these tools relies on the use of common ontologies. Medical terminologies are long-established foundational ontologies, allowing the retrieval of related and synonymous concepts, querying and cross-mapping multiple terminologies/ classifications at the same time. They culminate in the meta-thesaurus, which is a foundation product of the National Library of Medicine UMLS initiative[14], of which MeSH-2001 forms an essential part. It is a machine-readable knowledge source that represents multiple biomedical vocabularies organized as concepts in a standard format. Although it provides an immensely rich terminology in which terms and vocabularies become linked by a meaning, it does not include most telemedicine classifications, subheadings and qualifiers that require a new set of concepts. For that reason, the TM-BoK hierarchy [7] is essential.

Until now the above mentioned tools, could assist users in the process of cataloguing hierarchic content relationships for a set of documents, but did not address personalization issues, which are vital for multidisciplinary topics such as telemedicine.

The present e-learning platform that retrieves personalized medical information according to users profile and goals is an example. Furthermore, since agent technology is fundamental for intelligent queries and data retrieval, it becomes necessary to build health care agents specialized in the various health services using specific taxonomies and adapted markup languages. In this respect, AgentCities started a Health Care Working Group [15] in 2002; actively working in 2003 [16] and 2004 [17], their work apparent among agent specialists is not yet fully implemented by the medical community in the everyday medical applications[18].

In conclusion, the structure presented in this paper could create an Internet based distributed learning platform, with repositories placed anywhere. The system will keep the information on available learning objects/packages to access and retrieve information. Once loaded, the set of rules placed in the *modified*-XML-manifests stored anywhere, will be executed, presenting only data suited to users demands.

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Have published 111 scientific articles and 7 books on image analysis and technology; including the first and only existing text-book of Telemedicine: "Handbook of Telemedicine". IOSpress. Amsterdam 1998, ISBN 90-5199-413-3, translated in two more languages as in Spanish "Telemedicina" Ed. Medica Panamericana ISBN 84-7903-600-0 and in Greek: ΤΗΛΕΪΑΤΡΙΚΗ Ed Αναστασία Κασταvιά - O Ferrer Roca. ISBN: 960-02- Papazhsh Publ. Athens 2004. Since 2003 the proceedings of the Winter Courses are published and used as a textbook for the students. The previous editions were: CATAI 2004-Quality and Security in e-Health ISBN 84-609-0493-8; and CATAI 2005-Ambient intelligence in Medicine. ISBN 84-609-4000-4.

Founded the CATAI (Centre of Advanced Technology in Image Analysis) in 1994 being the president. Established at regional and national level, undertake international activities related with promotion of the information society and fight against technology transfer problems having the role of an "intermediate body". The association deals with information society developments being specialized and recognized abroad by its telemedicine work.

The innovation has been the prime motivation since 1968: Innovation in Tissue Culture and tumor cariotyping. First to introduce tissue culture of solid tumors in Spain in 1968 to demonstrate clonal evolution of tumours and the role of virus in their chromosomal anomalies in 1972, before the demonstration of oncogenes. (Estudio Etiopatogénico del Cáncer y su importancia Clínica I. Teorías Actuales de la Carcinogénesis. Teoría Vírica. *Med Clin 65*: 212-214,1975; *65*:256-259,1975; 65: 302-306,1997; *65*: 356-358,1975; Correlación Somático-Viral. Correlación cariotipo-tumoral *Med Clin 65*: 428-432, 1975 ; Consideraciones practicas de los cultivos tisulares. *Med.Clin. 65*: 528-534,1975; Clonal Evolution of Goiters. Pathologica, Pacini, Ed Pisa 145-151,1981)

First to introduce training and examinations with real cases and patients clinical records in Pathology, since 1972.

In artificial intelligence. Developped the program of automatic identification of cells in pathology (TEXCAN) to distinguish the chromatin texture of cells and their classification, used to teach cytology of thyroid and breast tumours.(Editor and author of the book : Análisis de Imagen I. Principios básicos de Tratamiento y Evaluación Estadística. Ed. Caja de Ahorros S/C Tenerife 1986 with 370 pages)

In image analysis. Developped the program of automatic identification of the immune-scores and DNA (TEXCAN) to evaluate the prognosis and treatment of the malignant breast tumors. Used to on line teaching of the importance of prognostic factors in breast tumors in pathology. Faculty of Medicine. (Author of the book Analysis de Imagen II. Aplicaciones. University of La Laguna 1990. 218 pages)

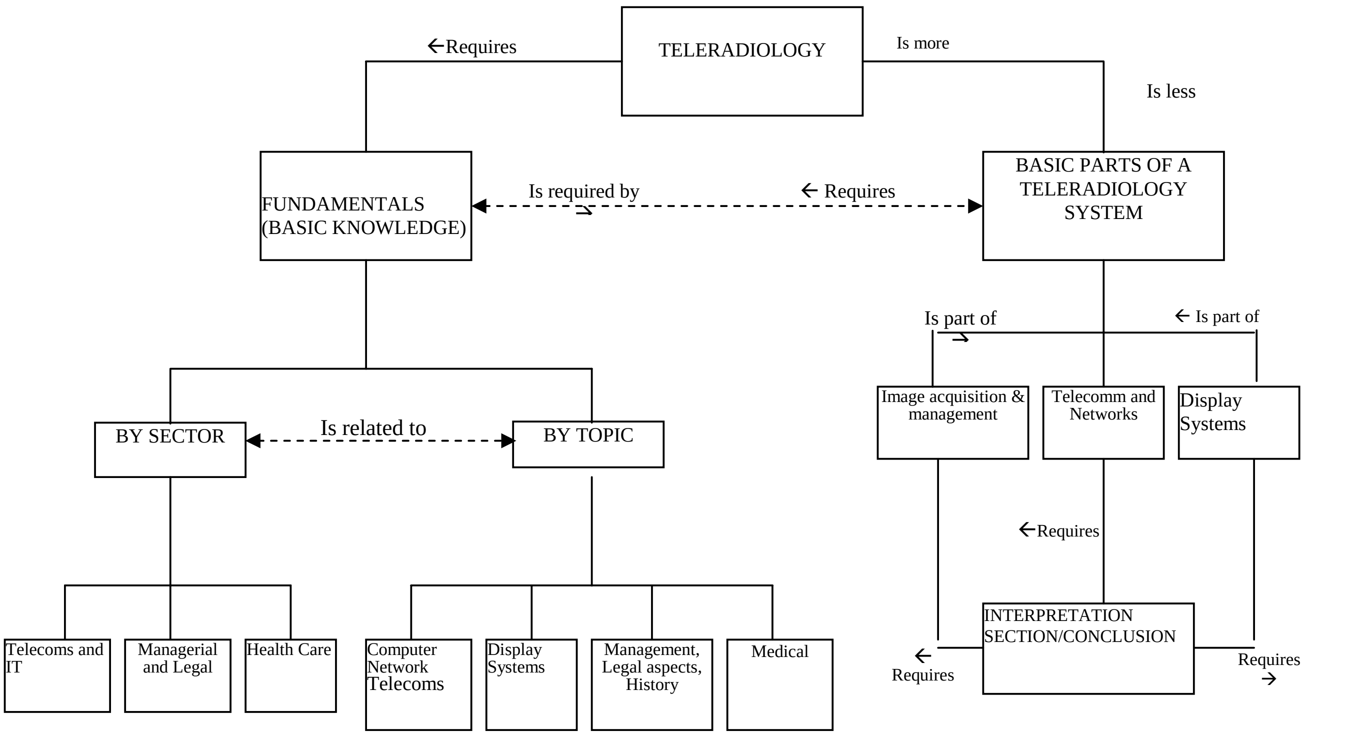
In the field of Telemedicine. First to develop a health care network of Videophones use for real tele-consultation and distant long-life learning for the doctors located in the small islands of Tenerife. The network called REVISA started in 1990. Since then, telemedicine was introduced to the students of the Faculty of Medicine.

Spread the use of information society tool and telecommunications tools in medicine since 1982 with international courses every year in the University of La Laguna. Courses starting with technical aspects moving big systems and devices for real training in the workshop area as well as distance training if available. Those courses were entitle since 1985 Image Analisis courses and in 2005 the 18th edition was programmed. Since 1993 started the International Winter Courses in Tenerife and the International Summer Courses in different European countries (Genova, Innsbruch, Udine, Berkshire,..) in 2005 the XIII edition of the Winter and Summer course have been developed. Those courses bring the most advanced techniques in the field of information society and telecommunication in Medicine. In 1992 we were the first in Spain to do distant tele-teaching by videoconferencing through ISDN. The ISDN was the first settle in Canary Islands and is still active. Training at distance was initially done with Norway and since 1992 distant training with videoconferencing to bring the expertise of people in different countries to our student in done every year. In 1999 a permanent 3-ISDN line for medical purposes was settle.

The use of distant image analysis evaluation for training purposes at distance was done with distant DNA evaluation in 1990 (first in the world) (Videoteléfono en Anatomía Patológica. Medición de DNA y Receptores inmunohistoquímicos a distancia. *Patología* 24:225-229,1991) Start distant teaching in Internet since 1993 with pathology and Image Analysis Courses. Since 1998 Winter Courses

were provided on-line in Internet for teaching purposes by means of real-player streaming video.
First in Spain and one of the first in the world to start Telemedicine teaching in the Faculty of Medicine. University of La Laguna. Spain. The topic is recognized in the new study Plan in Medicine since 1996 and in Informatics since 1998 as an optional matter. Telemedicine was introduced as free configuration matter since 1995.

FIGURE 4. Knowledge map nodes of Tele-radiology



Online Fundraising for Nonprofit Organizations

Pollach, Irene; Treiblmaier, Horst; and Floh, Arne

Abstract - ***Although the Internet provides nonprofit organizations with unprecedented opportunities for fundraising, the volume of online donations has been miniscule. Since one reason for this may be people's distrust in financial transactions on the WWW, we conducted a survey to gain insights into user trust in and attitudes toward online payment systems. The results indicate that people's trust in both the organization and the Internet are key factors in shaping their attitudes toward online payments, which in turn influences people's likelihood of using the Internet for financial transactions such as donations. Our findings suggest that nonprofits need to pay particular attention to donor relationships, process transparency, and transaction security in order to induce people to donate online.***

Index Terms - ***Fundraising, Online Payment, Non profit organizations***

1. *INTRODUCTION*

With the number of nonprofit organizations rising steadily, these organizations have begun to compete aggressively to attract and retain donors. The Internet provides the nonprofit sector with unprecedented opportunities for advocating issues, nurturing donor relationships, and streamlining the giving process. The present study looks at how environmental nonprofit organizations could leverage the capabilities of the Web to raise the volume of online fundraising. More precisely, the study seeks to identify factors conducive to people's propensity to use the Internet for financial transactions such as online donations. It first looks at the literature in the fields of philanthropy and nonprofit fundraising and then examines the nature of the relationships between donors and nonprofit organizations. Drawing on this discussion we empirically test a model explaining the conditions under which people complete financial transactions online and then discuss the implications of our findings for nonprofit fundraising.

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2. *LITERATURE REVIEW*

In view of the small body of empirical research on online fundraising in the nonprofit sector, we first examine three related strands of research – (1) donor motivation, (2) fundraising management and (3) nonprofit Internet usage – and then look at their implications for online fundraising of nonprofit organizations.

2.1 Donor Motivation

Research into donor behavior has identified a variety of reasons why people donate. Guy and Patton [19] argue that the strongest motive to donate is the deep-seated human need to help others. This intrinsic motivation is far stronger than extrinsic factors such as tangible or intangible rewards. The most effective activator of this intrinsic motivation is thus an appeal to this need to help others. For nonprofit organizations this means that donors must perceive the organization's cause as worthy of help, in which case their motivation translates into behavior, i.e. a monetary donation. Andreasen and Kotler [4] argue that all donors give because they expect tangible or intangible benefits in return, including for example public recognition, self-esteem, or relief from feelings of guilt [3][8]. Brady et al. [5] found that people also donate because they perceive a sense of obligation or a need, because they are attached to the organization, or because they have an innate or acquired philanthropic disposition. Hibbert and Horne [24] assert that situational stimuli are also a factor in donor motivation. For example, the way people are asked to donate has a significant impact on their willingness to give [15].

2.2 Fundraising Management

Another strand of research has looked at fundraising strategies. In most basic terms, fundraising builds a bridge between those with resources and those who need them [43]. What prevents most people from giving large amounts is the fact that donors cannot control what happens with their money and thus find it difficult to assess the quality of a nonprofit organization [39]. To raise awareness and persuade the public of the worthiness of their causes, nonprofits spend a large part of their marketing budgets on mass fundraising [24]. A 2002 study on donor behavior revealed that direct mail and word-of-mouth were considerably more effective in reaching donors than the Internet [17], suggesting that nonprofits do not yet benefit from the cost advantages provided by the World Wide Web.

Previous research on the effectiveness of fundraising has focused on donation requests and the segmentation of the donor market. Arguing that segmenting the donor market helps nonprofits to reach potential donors more effectively, several papers have looked at how variables such as income, intensity of appeals [38], personality [46], and attitudes [43] influence giving behavior, and how consumers respond cognitively and behaviorally to donation requests [39]. When making donation requests, appeals scales, i.e. menus of amounts from which the donor chooses, have also been found to exert a considerable influence on the amount people donate [9].

2.3 Nonprofit Internet Usage

The three basic functions of nonprofit Web sites are information, interaction, and fundraising [27]. Previous research on Web sites of nonprofits has focused on how nonprofits harness the power of the World Wide Web and e-mail [23] [32] [36] [37], how the Internet may provide them with a strategic competitive advantage [29], and how nonprofits engage audiences in two-way communication on their Web sites [40].

A problem inherent in the nonprofit sector is that marketing efforts, including state-of-the-art Web sites, are generally perceived as a waste of members' money [44]. Moreover, small nonprofits typically lack the time, money and expertise to develop sophisticated Web sites. As an alternative, they could use freely available features provided by third parties such as site statistics or forums, to enhance the functionality of their sites [27]. Community tools, in particular, have been considered conducive to the success of online fundraising, as they induce users to come back to the nonprofit's Web site and repeat visits to a site make people more inclined to support the organization's goals.

2.4 E-Philanthropy

Online fundraising has come a long way, since the late 1990s when a mere 1.2% of donors gave online and nonprofits were still struggling to align processes and technology to the new medium [33]. The literature on e-philanthropy tends to be normative and conceptual in nature rather than empirical, as noted by Amann and Khan [2]. Suggestions for online fundraising include, for example, placing a link to the donation page on the site's home page, accepting both credit and debit cards, and collecting e-mail addresses from donors to be able to send out donation requests in the future [12].

Sargeant [35] warns not to be too optimistic about online fundraising, as its success depends to a large extent on site traffic. He argues that only organizations that offer critical information, e.g. health-related organizations, will have high site traffic, which may results in sizable online fundraising volumes. Handy [22] asserts that membership in environmental nonprofits is motivated by emotions and values. Therefore, site traffic and thus successful online fundraising depend on whether Web sites manage to emotionally engage potential donors. It has been suggested that online donations significantly reduce fundraising costs for nonprofit organizations [12]. However, for smaller organizations, the initial and ongoing costs for accepting credit card payments may outweigh the additional funds raised.

As an alternative way of online giving, donation brokers have emerged on the World Wide Web. Cases in point are *All About Giving* [1], *Give Now* [18], or *Just Give* [26]. These brokers accept credit-card donations on behalf of charities, eliminating the need for nonprofit organizations to implement Web-based payment systems. Similarly, Web users can buy greeting cards from *Charity Cards* [6] and pick a charity they would like to donate the proceedings to.

3. A Framework for Analyzing Nonprofit and Business Relationship

Based on the above literature review, we posit a framework highlighting how relationships between nonprofits and donors differ from those between companies and customers. In order to analyze the peculiar features of the relationships between donors and nonprofit organizations it seems necessary to have a general look at some constituent elements of such relationships. Numerous academic papers have focused on the role of trust in relationships between consumers and business organizations, which underpin the assumption that trust can be seen as a necessary antecedent of customer retention, e.g. [16] [21][25][47]. Comparing various factors that influence trust, we argue that there are several noteworthy differences between nonprofit organizations (NPOs) and for-profit organizations (FPOs) (see Figure 1 and Table 1).

TABLE 1. A COMPARISON OF NONPROFIT ORGANIZATIONS AND FOR-PROFIT ORGANIZATIONS

Influencing Factor	NPO	FPO	
		Monopoly	Perfect Competition
Transparency	High	Varying	Varying
User Dependency	Low	High	Low
Service in Return	Mostly invisible	Visible	Visible

Nonprofits need to create high levels of trust since their service in return is in most cases not directly visible. Although nonprofits can strive to communicate their achievements and create a high level of transparency (e.g. by using different communication media), the direct benefit for the individual donor can usually not be evaluated easily.

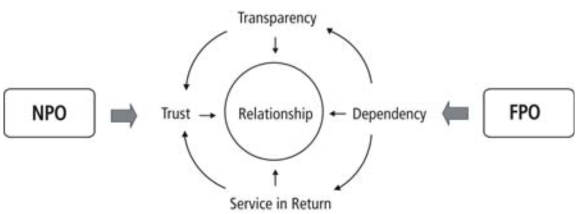

FIGURE 1. CONSTITUENT ELEMENTS OF BUSINESS RELATIONSHIPS

The service in return provided by for-profit organizations, on the other hand, is in most cases visible to customers. They may or may not be dependent on the goods or services an organization offers (e.g. monopolies vs. pure competition), which in many cases influences the level of transparency a company provides. Therefore, legislation ensures that certain minimum standards are observed, which many market dominating companies may not desire. It can be argued that nonprofits resemble small and medium-sized enterprises (SMEs) in many respects, especially concerning the need for transparency and the creation of trust.

3.1 Incentives and Disincentives of Donating

The process of donating (and especially donating online) is influenced by several factors. We have summarized the most important incentives and disincentives that may influence users' decisions of whether or not to give money online in Figure 2. As was pointed out above, several intrinsic and extrinsic motivators (e.g. sense of obligation, public recognition, or philanthropic disposition) exist, which, together with trust in the organization, may be seen as a sufficient reason for donating. On the other hand, distrust in the organization (especially concerning the use of funds), lack of disposable income or a negative attitude towards donating in general may inhibit a person from supporting nonprofit organizations. To a certain extent, the Internet affects both the incentives and the disincentives by adding advantages and drawbacks. One might argue that the speed and the ease of use of the medium may reduce transaction costs for both users and organizations [11]. This could be conducive to fundraising, especially when the donations are given spontaneously. However, the Internet may also be perceived as perilous and complex. In addition, privacy issues may arise when personal information is divulged [7][10][28].

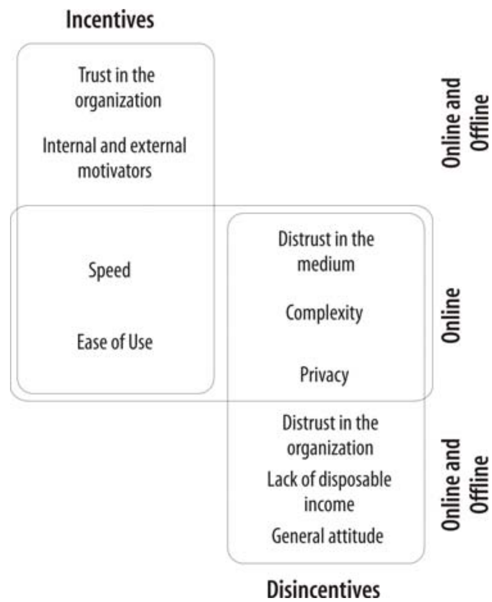

FIGURE 2. INCENTIVES AND DISINCENTIVES OF DONATING ONLINE AND OFFLINE

The opportunities and threats of online donations cannot be assessed without taking into account the role of the organization, which may be able to offset some of the disadvantages of the Internet by using secure connections and payment systems. Nonprofit organizations should also support users as much as they can during and after online transactions, e.g. by sending e-mail confirmations or offering online support. In addition, the possibility to easily cancel a transaction may help to build trust.

3.2 Virtual Relationship Building with NPOs

From a marketing point of view the relationship between a donor and a nonprofit organization can be characterized as very weak since this relationship may be discontinued at any time without any consequences for the donor. However, there may be a lot of intrinsic motivation that leads a donor to enter into such a relationship. Therefore, this motivation is considered a constituent element, as described above. The Internet offers a lot of additional opportunities for building and sustaining relationships and facilitating transactions. These opportunities equally apply to nonprofits and for-profits. In addition, the Internet can be seen as a medium that facilitates effective and efficient two-way communication [14] [41] and comprises a tremendous potential for online business transactions [42] or e-payment [45]. One starting point for examining the relationship between nonprofits and donors in online giving is people's trust in and attitudes toward the Internet as an instrument of payment.

4. *Methodology*

This study seeks to address the lack of empirical research in the area of e-philanthropy. It focuses on the role of trust in financial transactions on the World Wide Web, based on the assumption that trust is a critical factor when donors decide whether to give online or offline. We have therefore conducted an online survey among Austrian Internet users on trust in online payment systems. The results of this study may help nonprofits to determine in which areas they have to step up their trust building efforts to raise the volume of funds raised online.

We argue that people's attitudes towards online payment and their trust in the medium is the same in transactions involving nonprofits and those involving for-profit organizations. Therefore, we did not specifically ask about donations to nonprofit organizations in our questionnaire, since this might have introduced a bias in our data. A questionnaire focusing on online donations rather than online payments might have induced people to provide overly positive and thus inaccurate responses due to the "feel good factor" associated with charitable giving.

We chose the Austrian Internet users as our sample, since we wanted to assess the attitudes of those users who have a certain minimum level of experience with the Internet, i.e. who use it at least for e-mail communication. The Austrian Society for European Policy supported us by including a link to our questionnaire in its newsletter, which is sent out to a total of 3,542 users. Although no incentive was given for filling out the questionnaire, 631 people replied (17.8%). The survey was conducted between March 23 (the day the newsletter was sent out) and April 12th, 2004. A comprehensive pretest, including qualitative interviews with experts, was carried out to assure the understandability of the items.

We used self-programmed sliders to generate a magnitude scale instead of the commonly used category scales, thereby avoiding some weaknesses of the latter, e.g. the loss of information due to the limited resolution of the categories and the inadvertent influence of the investigator on the responses by constraining or expanding the range of options from which the respondents choose [30].

5. *Research Model and Hypotheses*

Based on the above literature review and drawing on the Theory of Planned Behavior, we have developed the research model depicted in Figure 3, which consists of five latent constructs. According to the proposed relations of the Theory of Planned Behavior (which have been confirmed by several Technology Acceptance Model studies), we hypothesize that users' past experience with online payments (EXP) has a direct influence on both trust in the organization receiving the payment (TRO) and trust in the Internet (TRI) when paying online. The concept of past experience refers to whether previous payments were successful and/or whether problems occurred during the transaction. Consistent with previous studies we further assume that the attitude toward e-payment (ATT) is positively influenced by trust [34]. Fishbein and Ajzen [13] found a positive correlation between the attitude toward an action and the intention (INT) to actually carry it out. More specifically, our hypotheses are as follows:

H1A: Past experience (EXP) with online payments positively affects trust in an organization (TRO).

H1B: Past experience (EXP) with online payments positively affects trust in the Internet (TRI).

H2A: Trust in the organization receiving the payment (TRO) positively affects the attitude toward making online payments (ATT).

H2B: Trust in the Internet (TRI) positively affects the attitude toward making e-payments (ATT).

H3: The attitude toward paying online (ATT) positively affects the intention to pay electronically (INT).

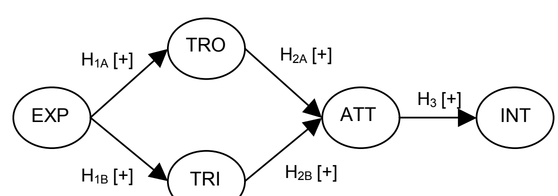

FIGURE 3. STRUCTURAL MODEL OF E-PAYMENT

6. *Results*

6.1 Hypothesis Testing

Structural Equation Modeling (SEM) appears to be the best available statistical technique for testing these hypotheses, since SEM includes the indirect effects of one latent variable on another [31]. Confirmatory analyses for each latent variable were used in order to assess construct validity.

The SEM software tool for all analyses was AMOS 4.0 (http://www.spss.com/amos). The data analysis generated a Chi-Square value of 214.145 (df = 71). The structural equation model in Figure 4 shows the standardized regression coefficients with their relevant p-values in brackets. It shows that all hypotheses and thus the theoretical model as a whole are supported by the data. All coefficients are statistically significant (p=0.001 or lower).

The results show a strong (positive) relationship between past experience with online payments and trust in the organization, while the relationship between experience with online payments and trust in the Internet is weaker. The attitude toward e-payment is strongly (positively) influenced by the two latent variables in the model (TRO, TRI). The intention to make online payments in the near future is strongly (positively) affected by the attitude toward e-payment.

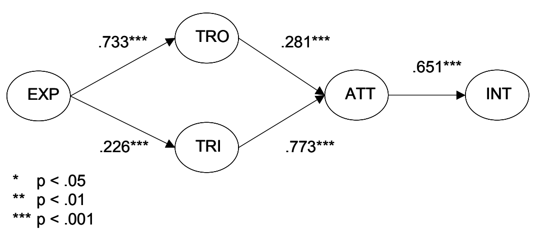

FIGURE 4. THE STRUCTURAL EQUATION MODEL

6.2 Goodness of Fit Indices

There has been considerable discussion on Goodness of Fit Indices and assessing the validity of structural equation models. Most of the software packages utilized for structural equation modeling calculate over 20 different indices. For this study, we selected seven indices, which have been widely used for reporting the validity of structural equation models [23].

TABLE 2. GOODNESS-OF-FIT INDICES (CF. [20])

Goodness-of-fit Measure	Levels of Acceptable Fit	Calculated Fit Indices
Goodness-of-fit index (GFI)	Higher values indicate better fit, no established thresholds	0.932
Root mean square error of approximation (RMSEA)	Average difference per degree of freedom expected to occur in the population, not the sample. Acceptable values under 0.08	0.070
Tucker-Lewis index (TLI) or NNFI	Recommended Level: 0.90	0.934
Normed fit index (NFI)	Recommended Level: 0.90	0.925
Adjusted goodness-of-fit index (AGFI)	Recommended Level: 0.90	0.900
Comparative Fit Index (CFI)	Recommended Level: 0.90	0.949

In our study, all of the six fit indices meet the recommended levels. As Table 2 shows, the theoretical model is supported by the data and is appropriate to explain and predict the adoption of online payments.

7. DISCUSSION AND CONCLUSION

The results confirm our hypotheses that past experience with online payment systems has a positive, direct influence on trust in the organization receiving the payment (H1A) and trust in Internet transactions (H1B), both of which positively and directly impact people's attitude toward online payments (H2A, H2B). The data also confirmed our hypothesis that people's attitude toward online payments affects their intention to use online payment facilities (H3).

As our model suggests, people will donate online rather than offline only when they perceive the organization as honest and trustworthy and consider the Internet a secure medium for financial transactions. Only then will their attitudes toward online payments – including both purchases and donations – be favorable, which in turn will increase their likelihood of using the Internet to make payments.

These results have several implications for nonprofits seeking to increase the portion of funds raised online. First, nonprofits have to be aware that every interaction between the organization and a potential donor may eventually have a bearing on whether people give at all and whether they give online or offline. To make sure that every interaction is a positive one, nonprofits should, for example, send donation requests only to those people who have opted to receive communications from the organization. Unsolicited communications may result in negative attitudes toward the organization, which may diminish people's trust in the organization. Also, segmenting donors into those who prefer online donations and those who rather donate offline may help to raise the volume of funds raised.

Further, nonprofits need to engender trust in their organizations and their fundraising activities, for example by disclosing how much they raise and how they use their funds. In addition, they could invite independent third parties to audit their organizations. Another way of shaping people's perceptions would be for nonprofit organizations to offer community tools on their Web sites. These may induce people to come back to the site regularly, which may have a positive influence on their perceptions of the organization.

To raise people's confidence in the Internet as a transaction medium nonprofit organizations should employ secure methods of data transfer and explain to users how they work. Also, they should provide information on their Web sites as to how online donations will be processed, what data are required to complete the transaction, and how the organization uses these data. Further, they may look to alternative ways of online payments, including for example, standing orders or direct debiting, in order to encourage people who do not have credit cards to donate online.

Clearly, people's attitude and propensity towards online payments is just one aspect of the complex relationship between online donors and environmental nonprofit organizations. Since our research has only focused on financial transactions, future research is needed to examine offline vs. online donor behavior and to study how environmental nonprofit organizations could build lasting relationships with potential donors.

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From Art to Industry: Development of Biomedical Simulators

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Abstract — ***The authors' methodology of creating e-learning content for the students of physiology, pathophysiology and biomedicine at the Faculty of Medicine is presented here. The design process from a formalized description of physiological reality to interactive educational software is described. Various tools are used during the design – starting with the numerical simulation software Matlab/Simulink, through Macromedia Flash for interactive animations, Control Web or MS Visual Studio for user interface design to web publishing tools including the Macromedia Breeze learning management system. Also, various professions are involved – teachers, physicians, simulation/modeling experts, graphic designers and programmers. The aim is to provide students with software that helps them understand the complex dynamics of physiological systems.***

Index Terms — ***Computer aided learning, e-learning, medicine, physiology, simulation models***

1. *Introduction*

THE process of medical e-learning content creation is a complex one. Interactive learning material promises to be more efficient than hypertext versions of medical textbooks with passive images, animations and video sequences. To provide interactivity, simulation models of real physiological systems are used to drive the animations based on the user's actions. The Department of Biocybernetics and Computer Aided Teaching possesses a multidisciplinary team and software development tools that cover all stages of the design process of educational simulators in medicine. The connection between multimedia presentation and physiological simulation models facilitates comprehensive demonstration of complex regulatory processes and their disorders to medical students and physicians alike.

Physiological simulations have a long tradition. Formalized description of the physiological reality starts with the pioneering work of Grodins et al. [1] in the end of 1960's. A classical milestone was a description of circulation by Guyton et al. [2] in the first half of 70's, the first large-scale model, which attempted to cover in broader perspective the physiological interconnections between circulation, breathing and kidneys. Since then, the number of studies that use computer models (mainly for evaluation and interpretation of experimental data) is steadily increasing. Likewise, simulation models can be used in clinical applications and medical equipment control (so called minimal models with a simple structure and a small number of parameters that can be easily identified from a particular patient's data) – e.g. a model of glucose metabolism [3].

Various approaches have been taken in the field of educational simulators. The aim of this paper is not to analyze the simulation models behind the simulators but rather the methods of their formalization (according to the Physiome project – http://physiome.org) and incorporation into educational software. Special attention is paid to the creation of web accessible graphical user interfaces – Microsoft .NET platform in combination with Macromedia Flash animations is provided as an alternative to commonly used Java applets or pure Flash web-based simulators [4]. The paper summarizes the authors' experience and achievements in this field.

2. *Educational Software Design*

Just as the reception of a text-book by students depends on the author's ability to explain complex material in an illustrative and comprehensive way, the key to success of multimedia educational software is a good scenario. Thus the *design cycle* of our programs (see **Fig. 1**) begins with the creation of scenarios. A scenario comprises not only of textual material, but also of the cartoon strips of the "storyboard" which will later help the graphic designers create graphics and animations.

There are more professions involved throughout the development cycle besides the already mentioned graphic designers and physiology teachers (responsible for the scenario). On the level of constructing simulation models, cooperation has to be established among system engineers (skilled in mathematical modeling), physiologists and physicians eventually, if the model is supposed to be applied in clinical medicine.

Educational software creation is concluded by application programmers and web designers, responsible for wrapping the simulation models

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with graphical user interfaces according to the scenario. The software then enters the testing phase in education and further refinements are made, if required by the teachers.

More on the respective phases of development will be given in the following paragraphs.

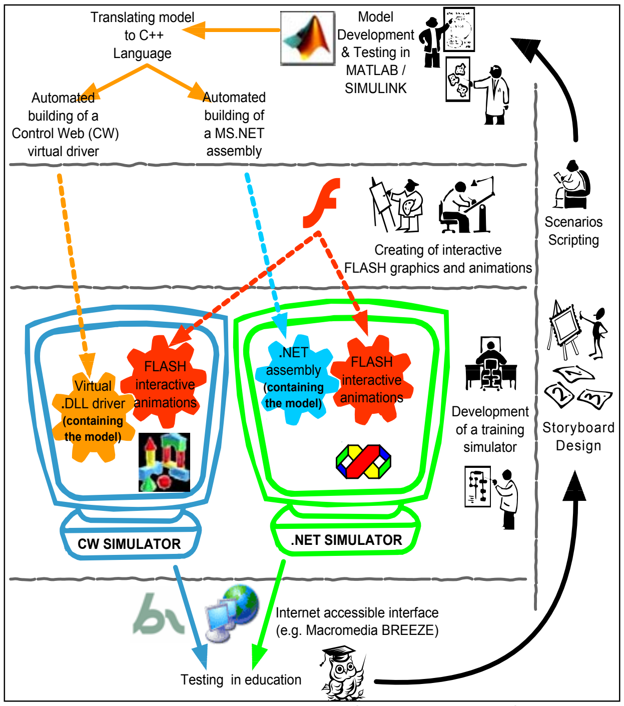

Fig. 1 The development cycle of educational software

2.1 Simulation models, chips and libraries

The heart of an e-learning application is a simulation model of a physiological system. Such a model is usually based on a system of differential equations, which have their origin in measurements on humans (either healthy or under pathological conditions). The biological reality is transformed into a formalized description in the language of mathematics.

On the other hand, a purely mathematical description is not suitable for further communication of the system engineer with physiologists or physicians (who are to judge the correctness and quality of the model). Thus MATLAB/Simulink graphical modeling/simulation environment has been adopted and physiological systems have been deconstructed into atomic blocks – *simulation chips*. These blocks represent elementary physiological subsystems; simulation models are formed by networks of these interconnected chips, thus keeping the organized structure of the original physiological system. A chip communicates with other simulation chips through defined inputs and outputs (corresponding to physiological quantities). All the mathematical expressions needed to implement the physiological function are hidden inside the chip. The simulation chips are then the common language of system science and physiology.

Once a simulation chip has been created, it can be of course reused in a number of simulation models. This idea gave birth to a Simulink library of physiological blocks – the *Physiology Blockset* (see **Fig. 2** and [13]).

2.2 Containers for simulation models

The MATLAB/Simulink environment is particularly good for professional creation, tuning and testing of simulation models, but due to its complexity it is not suitable for direct interaction with users. Solutions allowing rapid graphical user interface (GUI) development, and having sufficient computational power, at the same time had to be sought.

Two successful candidates for this post are available, both running on the Windows platform, are *Control Web* (CW), an industrial process control and visualization tool [6] and *Microsoft Visual Studio .NET*, a general purpose developer environment. Both of these tools can host the simulation model in the form of an external *.dll* library, provide rich means for creating GUI's and also allow incorporation of interactive Flash animations.

Fig. 1 reveals that the process of creation of the model library is automated with the help of Simulink Real Time Workshop (RTW), which translates simulation models to C++ language, links them with a proper differential equation solver and builds a *.dll*. The target platform of the *.dll* depends on a RTW template; templates for creating both CW driver and MS .NET assembly were created in our laboratory [7].

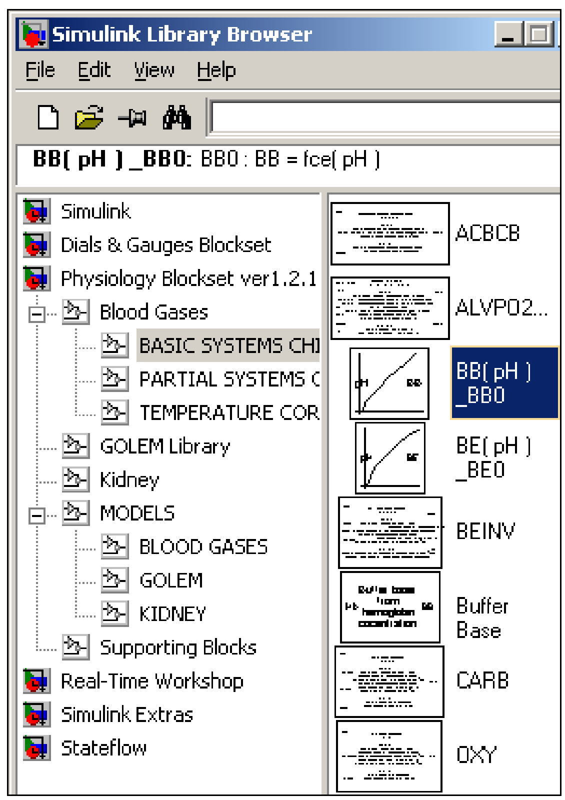

Fig. 2 Simulation chips, the bricks of simulation models, organized in a MATLAB / Simulink library

Creating graphical user interfaces

Besides the standard GUI elements (buttons, sliders, text boxes, data grids...), there is a need for special controls in our e-learning applications like knobs and meters for manipulating the simulation model inputs and outputs. This explains the choice of Control Web as one of the simulation front-ends, as it offers a wide range of these "industrial level" controls.

Some custom components also had to be designed from scratch, e.g. intelligent graphs and controls for manipulating vector inputs. When the graphical capabilities of the above mentioned integrated development environments are not sufficient, Macromedia Flash can be used to create interactive animations that can be inserted in both CW and MS .NET application, as well as in web pages. The Flash animations can communicate through the ActiveX interface, which means that they can be controlled from their host application.

An interesting example of a graphical control created in Flash can be seen in the simulator of mechanical properties of a skeletal muscle [8], where the control, in the form of a muscle fixed to an experimental stand, serves as an input and an output at the same time. The user can drag the muscle to a desired length using a mouse and during the electrical stimulation; the same graphic visualizes the muscle contraction.

In most cases, interactive graphics created with Flash are used to visualize the outputs of simulation models, e.g. a dilating/contracting blood vessel, a change in the respiratory volume and the breathing frequency of an alveolus.

2.3 UCM architecture and state management

As the structure of the simulation model gets more complicated and the educational scenario grows more complex, it is not efficient to connect the model directly to the presentation layer. *UCM architecture* and *State charts* offer an elegant solution to this problem.

UCM [4] stands for *User interface / Control object / Model layers*. The UCM architecture dictates a separation between functional layers, such as the user interface and simulation models, that are interconnected through the control object layer. The control object receives and handles events and messages from the interface elements (e.g. pressing the buttons, turning the knobs etc.) The control object may also receive events and messages from the model layer. Only the control object is allowed to communicate with the model layer. The control and model layer objects communicate by sending messages to each other. This centralizes access to the model layer and makes it perfectly clear what information the interface needs, when (in which context) the information is sought and how the internal functions can communicate with the interface.

The structure of the control object can be based on the *state engine* data structure combining a mechanism for managing context (the *state network*) with a mechanism for handling messages (see **Fig. 3**). The state network is a mechanism for keeping track of the current learning context of the user and of the current context of the simulated objects. The context can be changed as the result of messages or events from the user interface or from the model layer. As the current context changes the state network can be programmed with the actions to be executed – such as sending messages to the user interface layers (and consequently change some visual objects) or sending messages to the model layers (and subsequently change some model inputs, or request some model outputs).

For the visual description of the behavior of state networks we use a visual design methodology and notation called *statecharts* [5]. It is an extension of deterministic finite state automata (or state machines). For the design of the state network we use Stateflow, an extension of Simulink. Using Stateflow we can graphically describe and test the behavior of state networks for the tracking of simulated objects and learning context.

We have designed a special wizard that automatically converts the Stateflow statecharts into Microsoft .NET assemblies. These .NET components can communicate with the user interface layer (created with Microsoft .NET Visual Studio and with Macromedia Flash components incorporated in the Microsoft .NET environment) and with the model layer (containing simulation models developed using Simulink and converted into .NET components).

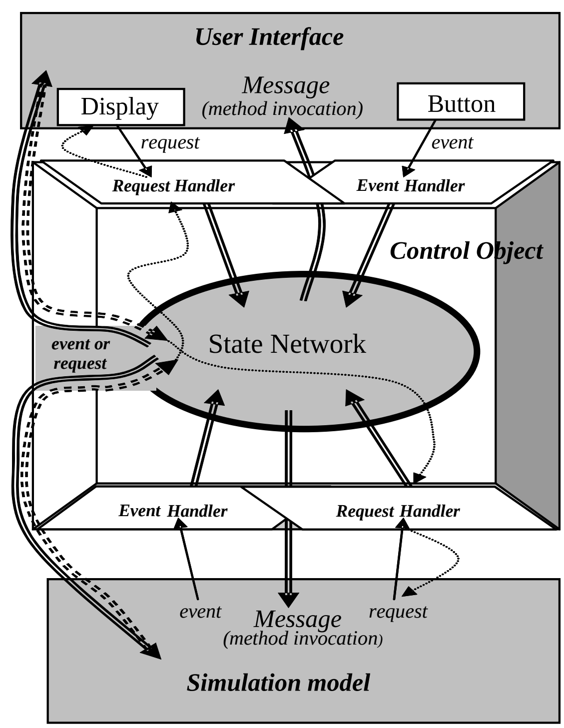

Fig. 3 UCM architecture and the state management

2.4 Putting it all together

The preceding paragraphs covered the characteristic phases of a medical simulator development – writing a scenario, simulation model design, converting the model to a linkable library, creating GUI elements and eventually a statechart. All these are put together in a standalone application – a simulator.

Model inputs and outputs (available through the linked library interface) are connected to respective control and visualization elements of the user interface (possibly through the Stateflow "control object") and the simulator enters the final stage of its development process – testing and evaluation in education. This might, of course, result in changes to the simulator or even raise demands for new simulation models. For an example of a user interfaces combining custom .NET controls and Flash animations, see **Fig. 4**.

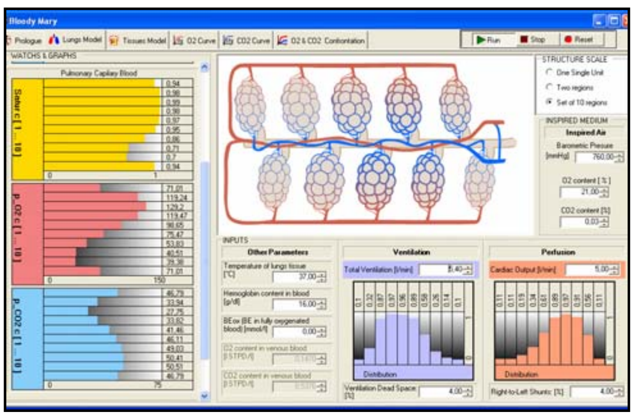

Fig. 4 An example of a simulator user interface combining custom MS .NET controls (bar graphs) with Flash animations (alveoli)

3. Deployment of Simulators in Education

There are two new interesting features brought to e-learning by simulation models – one is the scalability of the models and the other is the possibility of breaking the control loops of the model.

As for the *scalability* (both on the structural and time scale), one has to keep in mind that one level of detail of a model is not suitable in all situations. Consider a model of respiration – when explaining the disorders of the breathing mechanics, the time-course of every breath counts, while when tracking the effects of acid-base balance disorders on respiration, the time constant of the response is in the order of hours. The detailed model should be replaced with a simplified model with lumped parameters.

Another observation from the teaching experience with the simulation models is that better understanding of physiological functions is achieved through the *possibility of breaking the control loops of physiological regulations*. It means that just one input can be changed, while keeping the other inputs constant, revealing the dynamics of the subsystem (so called "ceteris paribus" principle).That's why our models allow students to switch various physiological quantities to manual control, thus avoiding the compensatory effect of other control loops.

A good example of a large scale simulator of the body-fluid balance, respiration, circulation and renal function is Golem [10], [11], **Fig. 5**. The simulator allows the user to set specific pathological situations and practice therapeutic interventions by changing input values. This "virtual therapy" promotes better understanding of the physiological and pathophysiological mechanisms without putting patient's health at stakes.

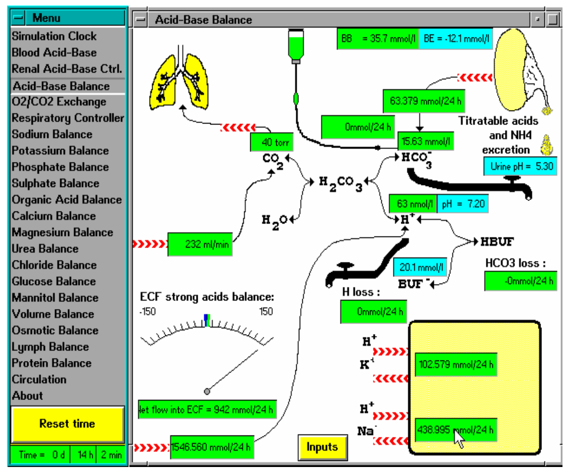

Fig. 5 Acid-base balance model in the Golem simulator, implemented in the Control Web environment

4. Web Accessible Simulators

The last problem to solve is making the simulators, as a part of the e-learning content, easily accessible to a large number of students. These efforts resulted in several approaches to web-accessibility of the models.

One of the possibilities is running the model on a server and exchanging only the input and output data with a client. The drawbacks here are obvious – for every connected client, there has to be a separate instance of the model on the server and the amount of data transferred between the server and a client per unit time is limited.

A better solution is *running the simulations on a client* while browsing the e-learning content on the internet. A direct method would be using a purely Flash simulator interface, because Flash applications can execute in the plug-in of a web browser. This method is feasible for simple models only (e.g. simulating the muscle contractions [8]), as Flash is not able to utilize the model in the form of the *.dll* library. The model equations have to be implemented in the native language of Flash – ActionScript, which is very slow due to its interpreted nature.

Currently the most promising architecture for delivering the e-learning content with simulation models over the internet is displayed in **Fig. 6.** The educational material is conceived as a web page containing text, graphics and Flash animations (possibly a Macromedia Breeze presentation) with hyperlinks to simulation models. The proper downloading and execution of the simulation models, as well as managing their context within the web presentation, is ensured by the model dispatcher, a component that is downloaded and installed prior to running the first simulation model [12].

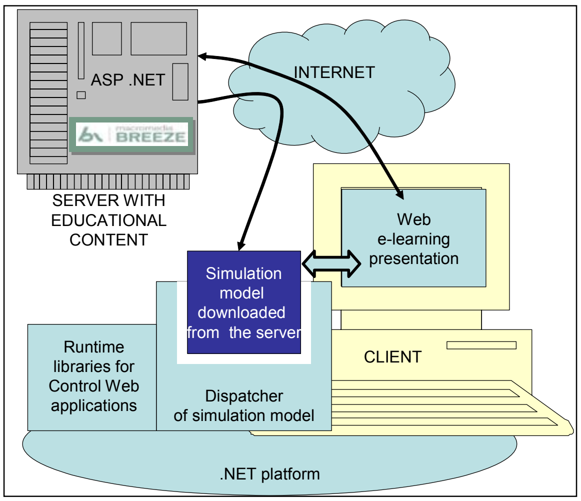

Fig. 6 Proposed structure of a modern e-learning system combining web accessibility with locally running .NET (or CW) simulators

The *Macromedia Breeze* learning management system offers a couple of beneficial features for e-learning content development – rapid creation of web accessible presentations from Microsoft PowerPoint slides accompanied by a spoken commentary and the possibility of preparing on-line test (with score reporting for individual students), to name just two.

5. CONCLUSION

The creation of modern educational software represents a challenging and complicated project requiring the team cooperation of various professionals: *Skilled teacher / physiologist* - who prepares the scenario (including the basic design of pictures and interactive animations) and tests the final products as a teaching aid. *System analyst* – an expert that designs, formalizes and tunes the simulation models in cooperation with a physiologist. The means of their mutual communication are the simulation chips in the Matlab/Simulink environment. *Graphic designer* - designs and constructs graphical components for simulator user interfaces and produces interactive animations in Macromedia Flash. *Application programmer / Web designer* - utilizes Microsoft .NET or Control Web as a container for the simulation model. He connects it with the interactive animations, and other multimedia features, and programs the actual educational application. And last but not least – the *student*, for whom the whole product is intended and whose comments and opinions after testing the program should be of high interest to the teacher and the developers.

It is clear that convenient developer tools and design methodology save time and money – particularly using appropriate specialized tools for the different types of tasks. We use MATLAB / Simulink (from MathWorks) for the development of simulation models, Stateflow (a MATLAB toolbox) for the visual description of the interactive scenario as statecharts, Macromedia Flash for the graphical design and scripting of the interactive animation components and Microsoft Visual Studio .NET or Control Web for the development of the final form of the educational program. For the interconnection of simulation models with the interactive multimedia user interface we use UCM architecture. The architecture describes the separation between the user interface and the underlying model behavior layers. When applied to the creation of interfaces, the architecture promotes good design practice because it centralizes the coordination of the user interface, making the interface behavior easier to understand, design and validate.

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Performance of a Parallel Technique for Solving Stiff ODEs Using a Block-diagonal Implicit Runge-Kutta Method

Kartawidjaja, M. A.; Suhartanto, H.; and Basaruddin, T.

Abstract—*Differential equations arise in many fields of application, such as in the simulation of phenomena in chemistry, physics, biology, medicine and so forth. These equations are generally in the form of initial value problems (IVPs), which can be extremely costly to solve when they are stiff due to the requirement of working with implicit methods. Implicit methods are costly because at each time step we need to solve implicit equations, which are nonlinear in general. Therefore, in such cases parallelization becomes an attractive approach.*

In this article we propose a parallel implementation of an ODE solver based on implicit Runge-Kutta framework. The parallelization is performed in two levels, i.e. across the method in solving the arising nonlinear systems and across the system in solving the associated linear systems. We use two kinds of test problems, the Brusselator and the Dense problems. The experiment was run on a cluster of PCs with PVM message-passing environment.

Our observations show that for the Brusselator problem, using parallelization will result in a better performance in terms of speedup for sufficiently large data. However for the Dense problem, the maximum attainable speedup is only two. We conclude that our two levels parallelization technique is only suitable for Brusselator type problems.

Index Terms—*message-passing, performance, PVM, stiff.*

1. INTRODUCTION

Many of mathematical models can be expressed in the form of IVPs for ODEs given in the following form [1]:

$$y'(x) = f(x, y(x)), \quad x \in [a,b], \qquad (1)$$
$$y(x_0) = y_0.$$

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where $y \to \Re^m$ and $f : \Re \times \Re^m \to \Re^m$. Higher order systems can always be written as systems of first order differential equations by introducing an additional vector and representing all derivatives accordingly. The solution of these ODEs can be extremely expensive due to the following factors:

- The dimension of the ODE is very large;
- The evaluation of the right-hand side factor is expensive;
- The interval of the integration is very long;
- The ODEs must be solved repeatedly.

It is widely believed that computationally intensive problems can be solved effectively using parallel computation.

There are three different techniques of parallelism. The first technique is parallelism across the method [2] that exploits concurrent function evaluations within a step or computes blocks of values simultaneously. The second technique is parallelism across the system [2] that involves decomposition of the problem into subproblems and solution of the subproblems concurrently. The last technique is parallelism across the step. This consists of strategy such as parallel solution of linear and nonlinear recurrences which are solved simultaneously over a large number of steps [3].

Several authors have designed and implemented ODE solvers. Their works are mainly based on construction of new integration formula which accommodates parallelism. For example, Suhartanto designed a parallel iterated technique based on multistep Runge-Kutta formula and implemented it using HPF90 technology [4]. Bendtsen designed a new formula based on Multiply Implicit Runge-Kutta (MIRK) methods which exploit parallelism across the method and implemented it using MPI (Message Passing Interface) technology [5]. De Swart designed a parallel iterated technique based on Implicit Runge-Kutta methods [6]. Bryne and Hindmarsh created MPI versions of PVODE from CVODE [7], a solver which is generated from two earlier solvers, VODE [8] and VODPK [9], by accommodating some parallel techniques [10]. The common part of the algorithms is the stepsize iteration (outer most loop) uses nonlinear iteration (Newton loop) to solve the nonlinear equation, and the nonlinear iteration uses some linear solvers. It means that there will be a linear solver loop if an iteration technique is used. We refer to it as inner most loop. However, none of those works investigate the effect of parallelism inside the inner most loop to the next outer loop (Newton loop) and further to the outer most loop (stepsize loop). Our research is aim to investigate this effect of parallelization on the overall performance of the ODE solver.

In this article we propose a parallel implementation of an ODE solver based on implicit Runge-Kutta framework. The parallelization is performed in two levels, i.e. across the method in solving the arising nonlinear systems and across the system in solving the associated linear systems. We use two kinds of test problems, the Brusselator problem which has a banded matrix structure and the Dense problem which has a full matrix structure. Because in general numerical methods have either banded or full matrix structures, it is reasonable to take those two models as test problems. Furthermore, stiffness of the problem, a factor that influences the rate of convergence of the solution, can be adjusted, and so can be the dimension of the problem.

2. A BRIEF OVERVIEW OF NUMERICAL CONCEPTS

2.1. Runge-Kutta method

An autonomous form of an *s*-stage Runge-Kutta method [3] is expressed as

$$Y = e \otimes y_n + h(A \otimes I_m)F(Y), \qquad (2)$$
$$y_{n+1} = y_n + h(b^T \otimes I_m)F(Y)$$

where Y represents the intermediate approximation vectors, *A* denotes the Runge-Kutta matrix and *h* is the step size. Using Newton iteration scheme results in the following linear system:

$$(I_s \otimes I_m - hA \otimes J)\Delta = G, \qquad (3)$$

where J is a Jacobian matrix. In order to reduce the computational cost, the Jacobian is evaluated at a single point [3], at y_0 for instance, and the method is called modified Newton method [3][1]. This Jacobian is computed either using analytical or numerical approach. If the users do not provide the analytical Jacobian, a numerical Jacobian is computed using finite difference method.

There are two diverse approaches to solve the linear systems, direct and iterative methods. Time complexity of direct methods equals $O(n^3)$ and of iterative methods $O(kxn^2)$, where *k* is the iteration step and *n* is the problem size. Thus, it is reasonable to consider the use of iterative methods to solve large linear systems. In our work we consider a widely used iterative method called GMRES (Generalized Minimal Residual) proposed by Saad [11] to solve the linear systems.

2.2. Error estimation

The estimation and control of errors are extremely important features in determining the accuracy of a numerical solution. A numerical method is supposed to produce a solution within a prescribed error tolerance. There are two measures of error commonly used, global error and local error. Although we are usually interested in global error which is the difference between the true solution and the numerical approximation, this error is not computable since we do not know the true solution in advance, besides it is difficult to estimate [12]. Therefore, most numerical codes estimate the local error and adjust the step size *h* in order to control the global error indirectly.

One technique to measure the local error is to use an embedding method introduced by Merson [13]. The idea of this method is to construct Runge-Kutta formulas which contain a second approximation $\hat{y}_n$ besides the numerical solution $\hat{y}$ and the order of those two formulas differs by one. The embedding process can be modeled by the following Butcher's tableau.

$$\begin{array}{c|c} c & A \\ \hline y & b^T \\ \hat{y} & \hat{b}^T \\ \hline & e^T \end{array}$$

The method defined by *c*, *A* and b^T is our numerical approximation that has order *q,* and that defined by *c*, *A* and $\hat{b}^T$ is the second approximation with one order higher or lower than the original method. Normally the embedded formula uses a lower order, i.e. $\hat{q} = q - 1$ [14]. The difference between the two approximations, $\hat{y}_n$ and y_n is used to estimate the local error

$$e_{n+1} = h\left\|\left(b^T - \hat{b}^T\right) \otimes I_m\right\| F(Y). \qquad (4)$$

There are many ways to measure the size of the estimated error vector. One way is to use a weighted root mean square norm [15] where the error is defined by

$$r = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{e_{n,i}}{ewt_i}\right)^2}, \qquad (5)$$

in which $e_{n,i}$ is the i^{th} component of the error vector and *ewt* is an error weighting factor written as

$$ewt_i = atol_i + \max\left(\left|y_{0,i}\right|, \left|y_{1,i}\right|\right) rtol_i \qquad (6)$$

The parameter *rtol* and *atol* are respectively the relative and absolute tolerances specified by the user. The former indicates the number of digits in accordance with relative accuracy taken at each time step, and the latter designates the value of the corresponding component of the solution vector. The estimated error at each time step varies with the stepsize with the aim of taking minimum number of steps while satisfying the error boundary.

2.3. Stepsize selection

An ODE integrator generates the solution by marching forward in time using one of the stepsize selection strategies, fixed stepsize or variable (adaptive) stepsize.

The simplest algorithms use fixed stepsize in the computation, meaning that a constant stepsize is used throughout the entire integration. However, this strategy can lead to excessive computation time especially when dealing with stiff problems where solutions have sharp changes. Therefore, modern solvers usually use algorithms that monitor the accuracy of the solution continuously and adjust the stepsize adaptively according to local truncation error calculated at each integration step. Stepsize should be chosen as such that it should be sufficiently small to cope with the sharp changes in the solution and must be as large as possible to minimize the computation cost and the round-off error.

A standard stepsize selection formula in integration of IVPs [15][16] is written as

$$h_{n+1} = \left(\frac{\varepsilon}{r_{n+1}}\right)^{1/k} h_n \,, \tag{7}$$

where r is the estimated error, k is a constant related to the order of the method and $\varepsilon = \theta.TOL$. The value of $\theta < 1$ is a safety factor to reduce the risk of stepsize rejection. Although determining the stepsize using standard stepsize strategy is widely used and successfully implemented, for certain cases more sophisticated methods are required.

Based on the knowledge in linear digital control theory, Söderlind introduced a PID (Predictive Integral Derivative) controller to control the stepsize. The general form of the PID controller [17] is given as

$$h_{n+1} = \left(\frac{\varepsilon}{r_n}\right)^{(k_I+k_P+k_D)} \left(\frac{\varepsilon}{r_{n-1}}\right)^{-(k_P+2k_D)} \left(\frac{\varepsilon}{r_{n-2}}\right)^{k_D} h_n \,, \tag{8}$$

where k_I, k_P and k_D are parameters of integral, proportional and derivative gains respectively. The family of filter based controllers can be classified using a notation of $Hp_Dp_Ap_F$, where p_D, p_A and p_F denote the dynamic order, adaptivity and filter order respectively. One class of this controller, *H211b*, is appropriate to solve medium to non-smooth problems as stated in [17]. This controller is defined by

$$h_{n+1} = \left(\frac{\varepsilon}{r_n}\right)^{1/(bk)} \left(\frac{\varepsilon}{r_{n-1}}\right)^{1/(bk)} \left(\frac{\varepsilon}{r_{n-2}}\right)^{-1/b} h_n \,. \tag{9}$$

In practice the value of b in equation (9) may be chosen in the range of 2 – 8, where larger values of b offer more smoothness of stepsize. Detail discussion of these controllers can be found in [17].

3. Parallel Performance

There are various metrics to evaluate performance of parallel systems, such as run time, speedup and efficiency.

A sequential algorithm is usually evaluated in terms of its execution time, and expressed as a function of the problem size. On the contrary, the execution time of a parallel algorithm depends not only on the problem size, but also on the architecture of the parallel computer and the number of processors involved in the computation.

A general model of parallel execution time [18] is formulated as

$$T_p = T_{comp} + T_{comm}, \tag{10}$$

where T_{comp} and T_{comm} denote computation time and communication time respectively. This model is an ideal model where only computation and communication processes are assumed to take place. However, in parallel environment the execution time will also incorporate waiting time of a processor, synchronization time or even collision time if exists. Thus, a more realistic model of a parallel execution time is

$$T_p = T_{comp} + T_{comm} + \delta \,, \tag{11}$$

where δ is the time a processor neither in the state of computing nor in the state of communicating. This parameter denotes the overhead in parallel computation and thus limits the speedup. The overhead can be caused by several factors [19]:

- imbalanced workload;
- the time spent waiting at synchronization level;
- extra computations in the parallel version which are not needed in the sequential version.

Unfortunately those issues are conflicting with one another and thus must be traded off. Unlike the computation and communication time that contribute to the parallel execution time in a straightforward manner, the parameter δ is difficult to be determined.

4. Problem Statement

We use two types of test problems, 1-D diffusion Brusselator problem and the Dense problem. The dimension of ODEs used in these two problems ranges from 100 to 700.

4.1. Brusselator problem

The Brusselator problem is modeled as [20]

$$\frac{\partial u}{\partial t} = A + u^2 v - (B+1)u + \alpha \frac{\partial^2 u}{\partial x^2}, \qquad \frac{\partial v}{\partial t} = Bu - u^2 v + \alpha \frac{\partial^2 v}{\partial x^2} \tag{12}$$

where u and v denote the concentration of reaction products, A and B denote the concentration of input reagents. The parameter $\alpha = d/L^2$, where d is the diffusion coefficient and L is the reactor length. The value of α determines the stiffness of the problem. In our work we chose A = 1, B = 3 and α = 0.02. The initial conditions are

$$u(x,0) = 1 + \sin(2\pi x), \qquad v(x,0) = 3. \tag{13}$$

Setting $x_i = i/(N+1)$ $(1 \le i \le N)$, $\Delta x = 1/(N+1)$ and discretizing the derivatives in equation (12) over a grid of N points yields

$$u'_i = 1 + u_i^2 v_i - 4u_i + \frac{\alpha}{(\Delta x)^2}(u_{i-1} - 2u_i + u_{i+1}), \qquad v'_i = 3u_i - u_i^2 v_i - 4u_i + \frac{\alpha}{(\Delta x)^2}(v_{i-1} - 2v_i + v_{i+1}) \tag{14}$$

with $u_i(0) = 1 + \sin(2\pi x_i), v_i(0) = 3$ and $i = 1, \ldots N$.

4.2. Dense problem

The Dense problem [4][21]] is defined by

$$y_i^{'} = (QY)_i + e^{-\sum_{j=1}^{i} y_j^2}, \quad i = 1, \ldots, m, \tag{15}$$

where $Y \in \Re^m, Y(0) = e, \ x \in [0,1]$ and $Q = Q_1^T D Q_1$. Matrix Q has orthonormal columns of a random dense matrix. The eigenvalues of matrix D can be adjusted and hence the eigenvalue spectrum of matrix Q can be adjusted as well. In our work we use matrix D with an eigenvalue spectrum that ranges from 1 to 10.

5. Implementation Issues

In our work we use a block-diagonal Runge-Kutta matrix proposed by Iserles and Norsett [22] which is a method of order 4. For the second approximation we use a third order method. The construction of the third order method has to obey a certain condition as described in [15]:

$$\sum_j b_j = 1, \quad 2\sum_{j,k} b_j a_{jk} = 1, \quad 3\sum_{j,k,l} b_j a_{jk} a_{jl} = 1, \quad 6\sum_{j,k,l} b_j a_{jk} a_{kl} = 1. \tag{16}$$

Because it is impossible to find a pair of order 4(3) for a 4-stage Runge-Kutta method, we use a method called FSAL (First Same As Last) as suggested in [15]. This method adds y as a fifth stage of the process. As a result we have four linear systems with five unknowns, and thus we must take an arbitrary value for one of the unknown. In order to have a relative small difference between vector $\hat{b}^T$ and b^T we set $\hat{b}_5^T = 6 \times 10^{-16}$. The modified Runge-Kutta matrix is thus given in Table 3.

Table 3 Modified Iserles and Nørsett pair formula.

$\frac{3-\sqrt{3}}{6}$	$\frac{5}{12}$	$\frac{1-2\sqrt{3}}{12}$	0	0	
$\frac{3+\sqrt{3}}{6}$	$\frac{1+2\sqrt{3}}{12}$	$\frac{5}{12}$	0	0	
$\frac{3-\sqrt{3}}{6}$	0	0	$\frac{1}{2}$	$\frac{-\sqrt{3}}{6}$	
$\frac{3+\sqrt{3}}{6}$	0	0	$\frac{\sqrt{3}}{6}$	$\frac{1}{2}$	
	$\frac{3}{2}$	$\frac{3}{2}$	-1	−1	
	$\frac{9.857143}{6}$	$\frac{9.857143}{6}$	$-\frac{6.857143}{6}$	$-\frac{6.857143}{6}$	6x10 $^{-16}$
	$\frac{0.857143}{6}$	$\frac{0.857143}{6}$	$\frac{0.857143}{6}$	$\frac{0.857143}{6}$	6x10 $^{-16}$

To control the error we consider the stepsize controller introduced by Söderlind that belongs to *H211b* class and set *b* = 4 as recommended in [17].

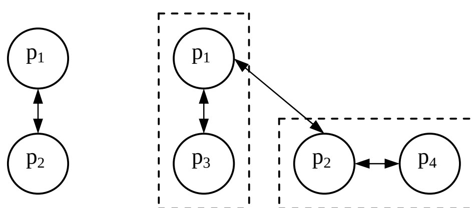
6. Parallel implementation

In our experiment we exploit parallelism across the method as well as parallelism across the system. Parallelism across the method is implemented for solving the nonlinear systems using Newton's scheme as discussed in [23], and parallelism across the system is employed for solving the linear system using GMRES method as presented in [24]. If there are only two processors available, parallelization is performed only using across the method to solve the two nonlinear systems simultaneously. If more processors are available, the parallelization across the system is also done to solve the linear systems. Figure 5 gives an illustration of the parallelization process.

If there are only two processors, after initialization p_1 sends vector Y_2 and stepsize h to p_2. Afterwards each processor builds its own Jacobian, and the succeeding computation can be carried out concurrently. If there are four processors or more, the resulting linear systems can further be parallelized, meaning that the two groups of processors, $p_1 - p_3$ and $p_2 - p_4$ as depicted in Figure 6, work independently in solving the linear systems and the exchange of data between those two groups only occurs at the beginning and the end of the computation, or if synchronization is needed, such as if convergence is not achieved after a predefined maximum Newton iteration and time step h needs to be reduced as a consequence.

```
Preprocessing
t_n = t_0
while (t_n < t_fin)
initialize Y
  if p > 1
    p_1 sends Y_2 and h to p_2
  end if
  Newton_converge := false
  while (not converge)
    call nonlinear solver -> parallelism across
                             the method [23]
      GMRES_converge := false
      while (not converge)
         call linear solver ->  parallelism across
                                the system [24]
      end while
  end while
  estimate error
  compute h_new
  t_n = t_n + h_new
end while
```

FIGURE 5 STRUCTURE OF PARALLEL ODE.



(a) Two processors (b) Four processors

FIGURE 6 PROCESSOR WORKING-RELATIONSHIP.

To ensure load balancing, the number of processors involved in parallel environment should be an even number. Since only four processors are available in our working platform, we could use only two and four processors in parallel and each process is mapped onto each processor.

7. NUMERICAL EXPERIMENTS AND RESULTS

The experiment was performed on a cluster of PCs, consisting of four processors with similar characteristics, connected through a 100 Mbit Ethernet link. Each PC has an INTEL Pentium III 450 MHz processor and 512 MB RAM. They run Linux Mandrake 8 and the test code was written in C. The measurement was performed in PVM environment that provides a collection of library routines for message-passing. Further details concerning PVM can be found in [25].

7.1. Brusselator problem

The performance curve of the solver for the Brusselator problem with finite difference and analytical Jacobian is given in Figure 7.

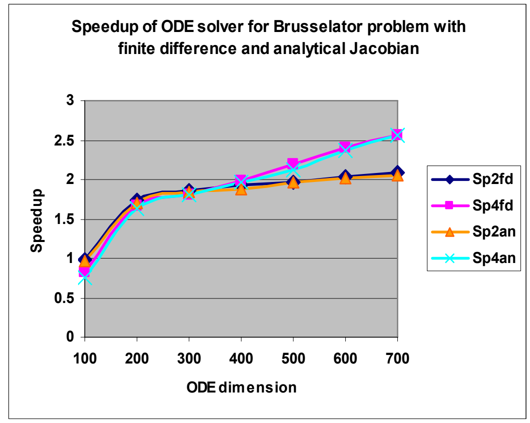


FIGURE 7 SPEEDUP OF ODE SOLVER FOR THE BRUSSELATOR PROBLEM WITH FINITE-DIFFERENCE AND ANALYTICAL JACOBIAN.

We note from Figure 7 that using multiprocessors will result in a better performance despite how the Jacobian matrix is provided except for ODE with small dimension, i.e. n = 100, where applying parallelization will result in a performance degradation because of the domination of communication time over computation time. We also observe that a superlinear speedup occurs for large size of ODE solved using two processors, i.e. ODE of dimension $n \geq 600$. This superlinear speedup occurs for ODE with either finite difference or analytical Jacobian. Superlinerar speedup does not reflect the actual performance gain, it is usually caused by the size of data which might be too large to fit into the main memory of a single processor.

Our observation indicates that solving the linear system requires approximately 50 to 70% of the overall execution time in each integration step. This large percentage of time will contribute to a better performance when more processors are available except for small data size, i.e. for ODE with dimension $n \leq 200$.

7.2. Dense problem

The performance of the Dense problem is illustrated in Figure 8. We note from this figure that a better performance can be achieved by using 2 and 4 processors.

For solver with finite difference Jacobian, we observe that approximately 95 to 99% of computation time is required to compute the Jacobian matrix and less than 5% to solve the linear systems. Because only two processors are involved in solving nonlinear systems, the maximum attainable speedup is two, and employing more processors will not contribute to speedup because of the very small amount of time is needed to solve the linear system.

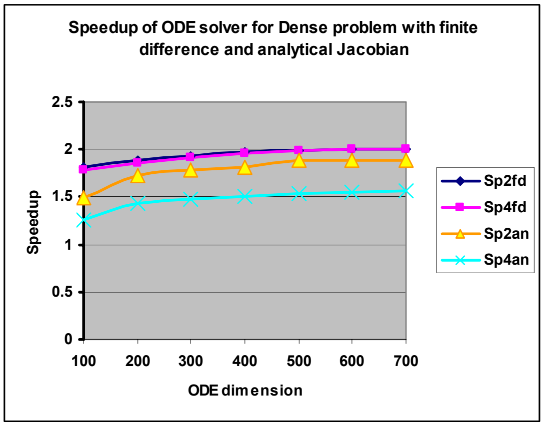


FIGURE 8 SPEEDUP OF ODE SOLVER FOR THE DENSE PROBLEM WITH FINITE-DIFFERENCE AND ANALYTICAL JACOBIAN.

For solver with analytical Jacobian, the computation time required to solve the linear system at each integration step is approximately 25 to 30% of the overall execution time. However, this amount of time is not large enough to contribute to the speedup by parallelizing the linear system, in contrary the performance will degrade. In other words, for solver with analytical Jacobian, the maximum performance is achieved by using two processors where only parallelization across the method is employed.

8. *CONCLUSION*

From the experiment we conclude that if solving the linear systems requires a large percentage of time as in the Brusselator problem, two levels parallelization will result in a better performance in terms of speedup. However, if solving the linear systems only consumes about 30% of the overall execution time as in the Dense problem, parallelizing the linear systems will not contribute to a better performance. Further experiment by incorporating more processors will be performed.

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An Analysis of Student Satisfaction in Higher Education Courses Delivered Online and in the Live Classroom

Abdul-Hamid, Husein; Howard, James

Abstract—*Regression analysis was used to compare degrees of student satisfaction with learning as affected by class size, technical content, interaction, feedback, and course duration. In online classes, having more students in a class enhances student satisfaction with the level of student interaction. In live classes, we find the opposite: larger class sizes have a negative effect on satisfaction with student-to-student interaction. Student satisfaction with instructor feedback in online classes declines with class size. Average levels of student satisfaction with technical courses taken over the Internet are significantly lower than with non-technical online courses. These findings are providing helpful insights to best practices research, especially in targeting the course activities, functions and format to achieve the best learning outcomes*.

Index Terms—*online, technical, education, student satisfaction, class size, learning, teaching*

1. Introduction

THIS paper addresses how class size, technical course content, and whether or not a course is accelerated affect student learning and satisfaction in college-level online courses compared to live courses. Previous research into student satisfaction with the delivery of higher education has primarily focused on the effect of class size.

The corresponding research questions are:

1. How does class size affect learning/student satisfaction in the live classroom compared to the online environment?
2. Do technical courses differ from non-technical courses in the levels of student satisfaction with the learning experience?
3. Do the levels of satisfaction differ for accelerated courses, compared to courses delivered over a fourteen-week semester?

While a majority of such studies over the past thirty years identifies a class size effect, the strength of this effect, in most instances, is small. Published research is most heavily concentrated in the undergraduate live classroom, where class sizes sometimes reach 600 students for introductory courses. The findings have been inconsistent, ranging from a small negative class size effect [1, 2, 3] to no significant class size effect [4, 5, 6]. Sugrue et al. [7] report on an experiment where an instructor taught the same MBA Managerial Finance course in two different environments (traditional live classroom and two-way video) and found that the class size effect on satisfaction was negative both for the classes taught using two-way video and for those taught in the traditional live format. An unpublished dissertation by Defusco [8] concludes that student satisfaction is maximized at a class size of 11-15 for adult students taking coursework over the Internet.

Scheck and Kinicki [9] surveyed 944 students taking live courses from a large southwestern university. Students were identified as attending a large (greater than 150 students) or small (38 students or less) class. When they analyzed the responses, they found that class size significantly and negatively affected teacher behavior (less satisfaction with teacher). In addition, large class size has a negative effect on student performance, defined as the grade earned by the student.

Hoffman, et al. [10] conducted telephone interviews with a random sample of 40 recent graduates from three college programs at a small liberal arts college. The graduates cited small class size as one of the major factors for their success in college and subsequently in the work place.

Hartman and Truman-Davis [11] administered a survey to 71 University of Central Florida faculty teaching in a variety of online and live formats and found from responses that optimal class size ranged from 25 for totally online classes to 42.5 for 100 percent live classes.

We were unable to find any published literature examining possible interrelated effects of technical/non-technical content and class size on measures of student satisfaction for courses delivered in a live format or over the Internet.

Examined in this study are several drivers of

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student satisfaction in live and online courses conducted in a large US accredited university, University of Maryland University College (UMUC), over six semesters, from the Fall 2001 semester to the Summer 2003 semester, using a large dataset consisting of student course evaluation data from 6,995 classes. Completing the course evaluation is mandatory for online students and is close to 100 percent in live classes. Class sizes in the study ranged from 15-55

2. Methodology, Data, and Model Description

The dependent/outcome variables in our models include the following:

1. Class drop/withdrawal rates
2. The degree to which the student feels the course stimulates interest for learning
3. The degree to which the student feels he/she is given adequate feedback to facilitate learning
4. The degree to which the student feels there is sufficient student-student interaction in the class
5. The degree to which the student feels there is adequate student-faculty interaction in the class
6. The degree to which the student is satisfied with the instructor as a facilitator of the learning activity
7. The degree to which the student is satisfied with the course and what has been learned
8. Student perception of the effectiveness of course pedagogy

Non-representative course data were deleted from the analysis (e.g., non-credit courses).

Linear regression analysis was employed to model the relationships between class size and the dependent variables described above. In addition to class size, other independent variables as described below were included as dummy variables. The model was tested for goodness of fit.

In this least squares model, the dependent variables (student satisfaction, class drop/ withdrawal rate) are regressed against class size, and the dummy variables defined for: technical/non-technical, undergraduate/graduate, regular/accelerated format, and live/online format courses.

We settled on this model after examining the residuals from the linear regressions. In performing various tests, we concluded the residuals exhibited a reasonably random pattern around the regression line and that the variances of the errors around the regressions were approximately normal and constant throughout the range of the dependent variables in the various versions of the model.

Model I:

The first phase of the analysis incorporates all the subpopulation categories as dummy variables into a comprehensive general model that includes graduate and undergraduate courses, accelerated and regular courses, live and online courses, and technical and non-technical courses. This yields one model X 8 dependent variables = 8 separate regressions.

The full model (Model I) is:

Dependent variable = a + b1*size + b2*tech + b3*school + b4*acc + b5*delivery + error term

where the expected value of the error term = 0 and size = beginning class size, the primary independent variable, and where the remaining dependent variables are defined as:

tech: non-technical (=0) or technical (=1) course
school: undergraduate (=0) or graduate (=1) course
acc: normal length (=0) or accelerated/summer (=1) semester
delivery: online (=0) or live (=1) course section

This regression is intended to show the average effect that class size and defined independent variables have on each dependent variable. The independent variables (other than class size) are coded as dummy variables for this form of the model. The coefficient of class size (b1) represents the magnitude of this effect for a one-student change in class size. We are particularly interested in the b2 coefficient, the effect of technical course content when controlling for the effects of other variables.

Model II

While there are numerous interesting findings possible from Model I, what it cannot tell us is also important. The coefficients do not show the effects of interaction between class size and other independent variables. We are interested in this interaction for class size and technical courses. In other words, we would like to be able to answer the question: What is the class size effect for technical courses in the categories undergraduate/graduate and online/live?

This deficiency in Model I is addressed by introducing an interaction term into the regression model, where class size*tech is entered into the model as a separate independent variable. We then derive the coefficient for the effect of class size on the value of the dependent variable (e.g., stim = stimulates interest) for technical courses by adding the coefficient of class size to the interaction coefficient.

We also introduce an interaction variable, size*acc, for the effect of class size on the value of the dependent variable for accelerated courses. For this form of the model, we run separate regressions for graduate and undergraduate school courses and for online and live courses. Separate regressions for the more homogeneous populations (the four subcategories) facilitate interpretation of the results and improve the robustness of the statistical results by removing important sources of variability.

Model II results in four regressions (one for each subpopulation) for each of the eight dependent variables (4 subpopulations X 8 dependent variables = 32 regressions).

In summary, we perform separate regression analyses for the four subpopulations:

1. Undergraduate live classroom sections
2. Undergraduate online classroom sections
3. Graduate live classroom sections
4. Graduate online classroom sections

3. *Model Results*

When we model student satisfaction and class size variables in the full model (Model I), we find that technical courses have significantly higher average withdrawal rates (by about 2%) than non-technical courses.

Technical courses tend to score lower on the measures of satisfaction by .12 to .24 points on a 5-point Likert scale. Live courses, on average and when controlling for other dependent variables, have a withdrawal rate 5% below that of online courses and score from .15 to .38 points higher on the measures of student satisfaction.

The effects of accelerated courses on the measures of satisfaction are positive, with a withdrawal rate 4.7% below that of regular semester courses and with scores on the measures of satisfaction .05 to .11 points higher on the 5-point evaluation form scale.

The described results for Model I are significant at the .001 level, with R^2 ranging from .078 to .174.

We then broke the data down for Model II into the four population subsets (undergraduate online, undergraduate live, graduate online, and graduate live) and reran the regressions with technical and accelerated courses entered as dummy variables. Variables are also included to capture the effects of class size on both technical courses and accelerated courses. Our purpose in this approach is to determine if the relationships observed in the Model I are the same or different across data subsets and to identify any incremental class size effects due to the technical or accelerated nature of a course.

We find that the most consistent size effect is the positive effect that class size has on student satisfaction responses concerning student-student interaction in online classes (R^2 of .075 and .025 respectively). We also identified a significant negative effect of class size on student satisfaction with faculty feedback in undergraduate live courses (R^2 = .088). These results are significant at the .001 levels.

Though weak, a negative effect of class size on feedback is observed for undergraduate online (.08 level of significance) and graduate online (.10 level of significance) classes. This finding is not present in graduate live courses. A plausible explanation for this divergence in findings may be that graduate students attending live classes have lower expectations of personal feedback from faculty. Or perhaps they interpret the instructor's feedback in the live classroom as being directed at them personally, whereas the online students expect more focused personal feedback from their instructors via email or via clearly directed comments posted in the online classroom.

In general, class size appears to have the most consistent effects on the measures of satisfaction in undergraduate online courses. Interestingly, these effects are positive for student satisfaction measures, except for the negative faculty feedback effect discussed above. Also, the withdrawal rate in online undergraduate courses declines as class size increases. We conclude that the capability of the Internet and the online medium to enhance the learning experience accounts for this effect.

On the other hand, class size negatively affects satisfaction in undergraduate live classes. In addition to the negative effect on faculty feedback, class size negatively affects student-student interaction and faculty-student interaction scores.

An explanation for the generally positive effects of class size in undergraduate online courses and the negative effects of class size in live courses may be due to the self-selection by students who prefer one format to another. Students taking courses online are likely to be more comfortable with the technology of the virtual classroom and have learned how to leverage the properties of the Internet to make their experience more enjoyable. Thus, they may be able to realize the benefits of larger online classes more easily than students who are less technology savvy and choose the live classroom instead.

Undergraduate students taking live courses voice the expected negative effects of larger class sizes, consistent with what is heard anecdotally from students and gleaned from the literature.

The class size effects on graduate online courses appear to be limited to a few instances. In addition to the weak (statistically insignificant) negative effect of class size on faculty feedback in online courses, there are positive effects of class size in accelerated courses and negative effects of class size in technical courses.

In live graduate classes, no significant class size effects are identified based on the technical or non-technical nature of the course. However, there are significant negative class size effects in live accelerated courses for stimulating interest, faculty-student interaction, and overall course pedagogy scores.

The effect of technical content on course withdrawal rates is generally negative. Withdrawal rates are higher for undergraduate online technical courses by 5.17% and for graduate live courses by 6.56%. However, there is no significant difference between the technical and non-technical withdrawal rates for undergraduate live and graduate online classes. In undergraduate live and online classes, most measures of satisfaction score from .11 to .44 lower for technical courses. The only effect on the measures of satisfaction identified for graduate technical courses is the lower course overall satisfaction score (by .21) for live courses.

The effect of accelerated schedules on course withdrawal rates is positive for undergraduate live courses. Accelerated undergraduate live courses have lower withdrawal rates (by 5.7%) compared to regular courses. The withdrawal rates for all accelerated graduate courses and undergraduate online courses are not significantly different from those of regular courses.

As class size increases, student satisfaction, on average, appears to peak at around 25 students (this was visually confirmed by observing the results of a quadratic regression, satisfaction with interaction versus class size). This applies to both technical and non-technical courses.

4. CONCLUSION

The results of this study have several important strategy implications for the design and delivery of higher education in live classrooms and over the Internet.

Technical courses achieve lower satisfaction scores than non-technical courses, and this gap appeared in courses taught both online and in the live classroom. Thus, one strategy would be for course designers and faculty to collaborate in developing more effective approaches for the design and delivery of technical content in both environments, online and live classrooms.

Instructor feedback is important in both technical and non-technical courses. As class size increases, student satisfaction with feedback generally declines, slowly at first, then more rapidly as class size approaches 25. In light of this, online faculty should be trained to develop class management competencies that help facilitate classroom interaction and help them to efficiently provide substantive feedback to students. Our findings could help academic administrators when deciding on suitable class size for a technological environment. In order not to compromise student satisfaction, they should consider the amount of interaction and feedback that are required in a specific course and accordingly provide services and teaching support to that course instructor.

Opportunities for students to interact amongst themselves and with the instructor facilitate the learning process, as reflected in student evaluations. Thus, online courses should be designed with a significant interaction component to take advantage of the network property of the Internet.

Students in our study demonstrated significantly higher levels of satisfaction with both online and live classroom accelerated courses (e.g., an 8-week semester compared to a 14-week semester). This may be because the faster pace requires students to focus more on the content in a compressed timeframe and this enhances their learning experience. Accordingly, colleges and universities may wish to pilot and evaluate various accelerated course schemes as a means to improve the effectiveness of their curricula.

We did observe that higher withdrawal rates are present in the beginning courses of an online technical program (e.g., financial management, accounting). We believe a contributing factor to this situation is the difficulty beginning students have getting comfortable in the new medium and simultaneously mastering the fundamentals of the discipline. One recommended intervention is to populate these beginning online technical courses with tutors to work with students in solving problems, taking quizzes, and responding to questions regarding concepts and principles. A pilot tutoring project being conducted at the University of Maryland University College has yielded early positive results in significantly decreasing the withdrawal rates in these courses.

Best practices research has identified that teaching in a highly technical -and mainly online-environment is very challenging. In order to achieve successful student learning outcomes the research recommends restructuring the course delivery and design to engage the learners by stimulating their interests while promoting higher order learning skills. This research shows that, while pursuing the restructuring efforts, it is important to consider class size and its relationship with the levels of interaction and feedback in order to maintain high level of student satisfaction and learning.

It is important to note the limitations of this study. We only used student measures of satisfaction and learning. This is a first step toward a more systematic study with pre- and post-test instruments to measure the learning that occurs in classes of all types and sizes in the online environment. This would greatly facilitate not only accreditation but provide a sound framework for future class size and best practices research. It is noted that while online education is new, the education literature confirmed the relationship between student ratings and satisfaction. Abrami, d'Apollonia, and Cohen [12] point out, "Student ratings are seldom criticized as measures of student satisfaction with instruction..."

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Sustainability and Safety: The Complex System Properties

Afgan, H., Naim; and Carvalho G., Maria

Abstract— ***In the assessment of long term behavior of the complex system we introduce the notion of sustainability as the measure for the quality of the system. It is defined as a new quality which is measuring the ability of our society to secure and not compromise the ability of future generation to have quality of the life at least the same as our generation. This definition is a new approach to the definition of the comlex system property.***

The safety property of complex system is immanent to any system. It reflects quantitative merit for degradation of the system. Also, it includes rate of changes for any process leading to degradation of the system. Environmental degradation is among the most pressing global issues confronting modern society.

Sustainability and safety are linked with the similar essential idea to prevent degradation of the quality of the system. The sustainability is defined as the aggregation function of physical, social, technological, environmental and resources parameters. The safety is time derivative of the sustainability index. It was shown reference example of application of the multi-criteria evaluation with Sustainability and Safety Indexes of complex system. In conclusion, the evaluation of complex system is involved in the sustainable development research with associated uncertainty.

Key words—***complex system economic, environmental, technological and social indicator, indexes, multi-criteria evaluation, resource, safety, sustainability***

1. INTRODUCTION

The paper is an attempt to introduce the sustainability definition in the evaluation of the complex systems. By the introduction of sustainability notion as the proprety of the complex system a new approach is developed and applied in the selection ana assessment of different systems.

The vulnerability of modern world is an important issue to our humanity. For this reason it is of great importance to understand the state of system which may lead to the hazardous degeneration of any life support systems [1]. We now live in the world with treats that most of our sophisticated man made systems may become source of the hazardous species which may effect human lives. Fundamental safety consciousness is a challenge for understanding the need for the development of appropriate methodology for the assessment and evaluation of potential standard for safety. We are witnessing everyday that the safety notion is a key issue in human life. It has effects with individual and collective consequences in long term and short term span of time.

The development of sustainability science has become ultimate goal of modern society [2]. Like any other knowledge the safety science is cumulative resource of human history. Number of hazardous events is increasing which may be justified as consequence of the need for the better understanding individual events as much as the notion of collective properties of life support systems. It is immanent to any life support system to be described with the respective properties representing collective set of individual indicators. Relation between the safety properties of complex system and any other property of complex system is the fundamental quality indicator of the system..

In the assessment of long term behavior of the system we have to introduce notion of the sustainability as the measure for the quality of the system.[3,4] It is defined as the quality which is measuring the ability of our society to secure and not compromise the ability of future generation to have quality of the life at least the same as our generation. This measurement is aimed to facilitate control of the steady state of our systems. The safety of any system is closely linked to the change of quality of the system. It is known in thermodynamics that any change of the entropy of the system is directed to its maximum. If we look at the global scale of complex systems the maximum entropy will mean the death of the system. If we consider complex system defined with sustainability as the indicator of its quality, it is logical to assume that the time change of sustainability of the system may be used as the measure for the potential changes of safety of the system. Even it was accepted that present science is not in position to allow us to explain or model the complex system in the world, in the past number of years the attention was focused to study phenomena that seemed to be governing the spontaneous appearance of novel structure and their adoption to the changing environment [5]. Most of the life support systems

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are convoluting to the formation of the new structure and require a new approach in the evaluation of the system. The complexity of the systems is increasing in current decade.. There are many reasons. Among those are: ontological changes, epistemological changes and changes in the nature of decision making.. Sustainability development requires integrating economic, social, cultural, political and ecological factors. From the scientific viewpoint there are two basic task: one is the identification and understanding of the most important is the linkages between different factors and different scales that originate the possible changes in one component of the system into other parts of the system. The other task understands the dynamic of the system.

Environmental degradation [6] are among the most pressing global issues confronting modern society. Investigation of the potential capacity of the complex system to cause environmental degradation is an important goal of modern science. The study of these problems has imposed the demand for the assessment of safety properties of complex system [7]. In this respect definition of the safety property of the system is the essential parameter which define the adaptability of the system to its surrounding. Since sustainability of the complex system is by itself its property of the system, it is acceptable to take the sustainability change as the property indicator for the safety of the system.

Sustainability and safety are linked with the similar essential idea to prevent degradation of the quality of the system. As sustainability is defined as the aggregation function of the physical , social, technological, environmental and resources parameters it can be defined that the safety is time derivative of the sustainability indicators. Abrupt change of the sustainability will lead to the disastrous degradation of the system. Similarly, it can be taken that any adverse change in the sustainability indicator as the respective measure for the safety degradation of the system.

2 SUSTAINABILITY

Sustainability comprise complex system approach in the evaluation of the system state. By its definition sustainability include definition of quality merits without compromising among different aspect of system complexity. It is of paramount importance for any system as the complex system to quantify elements of complexity taking into a consideration various degree of complexity. As regards complexity elements of the system it can be codified as the specific structure reflecting different characteristics of the system .

Any process is characterized by the entropy production as the measure of the irreversibility of the processes within the system.. So, the complexity element of the system is reflecting internal parameter interaction can be defined by the entropy production in the system.. In the complexity definition of system one of the element is entropy generation on the system or energy losses in process [8]

Complexity elements of the economic indicators are structured in different levels are intrinsic to the specific levels and are measured in different scale. In the classical evaluation of system the economic merits are of primary interest. Since the economic quality is reflecting optimization function imposing minimum finale product cost , there are a number of parameters which are of interest to be taken into a consideration in the mathematical model for the determination of the optimized values of required for its evaluation .

Mutual interaction between the system and its surrounding is immanent for any life support system. As it is known the system is taking material resources from the surrounding and disposing residual to the environment. Among those residuals are the most important those which are in gaseous form and are dissipated to the environment. Also, most of the energy system is disposing low entropy heat to the environment

The social element of complexity of the system is property of the complex system.. In the social aspect of the system is included risk of environmental changes, health and nuclear hazards and may have to deal with a compounding of complexity at different level. Also, under social constrain reflecting social aspect of complexity of energy system are added values which improve the quality of the human
life.

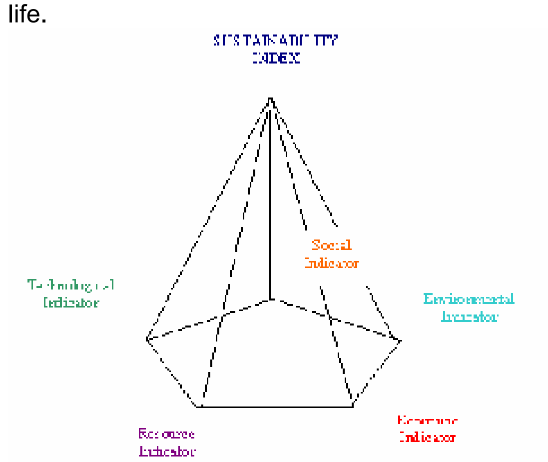

Fig. 1 Sustainability Index Structure

The technology quality of the system is the element of the complexity of the system. It may be defined and qualified as the potential upgrading of the individual part of the system and also as the interrelation among the elements. In the language of complex system this property can be understood as the inherent creativity of spontaneous appearance of novel structure.. Thermodynamically, information introduced in the system is the negentropy as the result of the change in the structure of system leading to the better performance .

Fig.1 shows graphical presentation of multidimensional Sustainability Index which is expressed as the additive function of the indicators multiplied by the respective weighting coefficients.

3. SAFETY

In the decade from 1991-2000, natural disasters killed a reported 665,598 people, probably an underestimate. And every year over 211,000 people are affected by natural disasters - two-thirds of them from floods. The number of weather-related disasters (droughts, floods and storms, for example) has doubled since 1996 while the number of geophysical disasters (e.g. earthquakes and volcanic eruptions) has remained steady over the last decade. And while floods cause the most damage, earthquakes run a close second, causing nearly US$270 billion of damage in the decade from 1991-2000.

The risk of natural disasters is often known and some preventive measures can be taken to protect human life, using selected materials and practices for building, avoiding flood-prone areas, etc. But it is often impossible to protect historic monuments from damage. Local authorities might also draw up a disaster action plan that could include briefing emergency services on how to limit the damage.

The safety of complex system property is immanent to any system. It reflects quantitative merit for the degradation of the system. Also, it includes rate of changes for any process leading to degradation of the system. It may be seen as the potential property predicting total degradation of the system. It is commonly known that any degradation of the system precede with the changes of the main properties of the system. Since sustainability is a complex property of any system the description of the sustainability change in time scale will lead to the possibility to define those rates of changes which may have different consequences. There are different disasters which are reflection of the specific causes. [9].

Taking into a consideration the change of individual elements of complexity we can design quantities which are of importance for definition of the potential states leading to the degradation of the system. In this respect we can analyze all elements of the complexity of the system and their change in the time scale.

Any process in the system is characterized with the entropy production as the measure of the irreversibility of the processes within the system.. The stationary state of the process is characterized by the constant entropy production[15] Non linearity of any process leads to the very fast degradation of the system. Typical example of this type of process is explosion. So, the rate of changes of entropy production in the system can be taken as the characteristic quality of the system which describe safety of the system.

The change of economic elements of indicator is intrinsic to the specific characteristic to be measured in the time scale. The time change of the economic indicators is common to the classical evaluation of system.. Any crises of the economic system is preceded with corresponding changes in the economic indicator of the system. Qualitative measurement of these indicator changes may lead to the forecast of the economic crises which is only one element of the potential disastrous changes of the system effecting its safety. Fig. 3, shows schematic presentation of Safety Index.

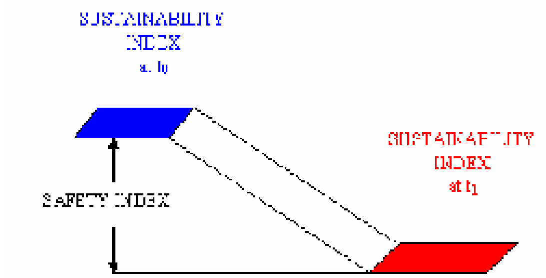

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Fig. 2 Schematic presentation of Safety Index

The mutual interaction between the system and its surrounding is immanent for any system. The changes in the interaction rate will effect the safety of the system... If this processes are in steady state it can be considered that the system safe.. As good example for this type of changes of indicators is the interaction of the system and its surrounding in the case of radioactive leaks from the nuclear facilities, which may lead to the hazardous consequences.

The change of social element of complexity of the system is property of the complex system.. The social aspect of the system includes the risk of environmental changes, health and nuclear hazards and may have to deal with a compounding of complexity at different level. It is of interest to notice that some of the social changes are an inherent characteristic of the system. As example we can take any strike which is result of the economic changes of the system. Similar example can be seen if there is sudden change in the environment which will lead to the social disturbance .

4. MULTI-CRITERIA EVALUATION OF SUSTAINABILITY AND SAFETY

The complex system requires special methodology for the evaluation. Since complexity of the system is closely related to the multi-dimensional space with different scale, the methodology has to bear multi-criteria procedure in evaluation of the complex system.

The method for multi-criteria evaluation and assessment of complex system has proved to be promising tool for the determination of quality of the system. Even it was shown that there are some deficiencies in the presented method , it is a new route in tracing future analysis of complex system.

Sustainability comprise complex system approach in the evaluation of the system state. By its definition, sustainability include definition of quality merits [10,11]. It is important for the assessment of any complex system to quantify elements of complexity taking into a consideration various degree of complexity. The complexity elements of the system can be codified as the specific structure reflecting different characteristics of the system [12,13]. It should include description of the interaction of internal parameters of the system and the system interaction with the different aspect of socio-economic-environment of ecosystem. The adoption of system to its surrounding leads to the physical, social and environmental interaction between the system and its surrounding. If there are number of different systems to be compared taking into a consideration potential behavior of individual system in the same surrounding there must be potential option which will give quantified quality priority among the system under consideration.

In order to define quantities which are used as measuring parameters in evaluation of the systems a following definition of qualities are adapted [14]:

1. Resource quality
2. Environment quality
3. Technological quality
4. Social quality

4.1 Resource Quality

Complex system is composed of number of elements which are connected with the aim to perform specific function,. The organization of the system elements is reflecting optimized structure of the system following specific pattern. The material conversion characterization is thermodynamically justified process with optimal internal parameters of the system. In this respect the quantification of thermodynamic quality of the system is reflecting number of parameters which are defining the design of the system.. Otherwise, it can be stated that the complexity element of internal processes in the system can be defined as the quality of material conversion measured by the thermodynamic efficiency of the system or any other parameter including integral parameters of thermodynamic system [15]. The material conversion process is characterized by the entropy production as the measure of the irreversibility of the processes within the system. So, the complexity element of the system reflecting internal parameter change and can be defined by the entropy production in the system [16]. Lately it is becoming popular to make energy analysis of the system as the tool for the quality assessment of the system as whole and also determine energy losses in individual elements of the system [8]. In this case the complexity element is entropy generation on the system or energy losses in conversion process.

4.2 Economic Quality

Any complex system evaluation has to include economic validation of the product and it has to be the basic building block of the assessment procedure [17]. Also, it is indispensable element of the complex system. The quality of complex system has to comprise the economic validation of the system. as the element of complexity. The main characteristic of the economic quality of the system is defined by the parameters comprising individual sub-elements of complexity reflecting economics of the system product. It is usually accepted to determine the economic indicator as the reflection of those sub-elements of complexity which are in the different scale. For this reason formation of fuzzy set of indicators for the consideration of energy system options is not trivial and has to reflect different conception of the system. Complexity elements of the economic indicators are structured in different levels are intrinsic to the specific levels and are measured in different scale. Since the economic quality is reflecting the optimization function imposing minimum finale product cost , there is a number of parameters which are of interest to be taken into a consideration in the mathematical model for the determination of the optimized values required for its evaluation [18].

4.3 Environment Quality

Mutual interaction between the complex system and its surrounding is immanent for any life support system [19]. For the complex system there are number of interaction which are defined by the respective parameters. On the first place, these interactions are the effects of system on the environment. As it is known that every system is taking material resources from the surrounding and disposing residual to the environment. Among those residuals are the most important those which are in gaseous form and are dissipated to the environment. Also, most of the complex systems are disposing low entropy heat to the environment. So the interaction between the system and environment is defined by the amount of material and energy transferred. The assessment of these interactions between the system and environment leads to recognition of the new element of complexity of the system. The basic components of environmental complexity element will be used in the assessment of the quality of individual system among the number of options under consideration. Every complex system is entity with the strong interaction with environment. There are ontological changes i.e human-induced changes in the nature proceeding at unprecedented rate and scale and resulting in grooving connectedness and inter dependency. Molecules of carbon dioxide produced in the energy system leads to the global climate changes and adding new element to the complexity of energy system.

4.4 Technological Quality

The complex system structure organization is subject to the constant development in order to improve its functionality and performance quality.[20]. The adoption of the system to the new requirement is complementary to the organization changes as the property of the complex system. The assessment of technological development implies adaptability of complex system to its evaluation. Information technology has demonstrated that its application to any system can lead to the intelligent system with self controlling ability. The potentiality for further improvement can be seen as the potentiality for self-organization of the system. This can be achieved with the use of information knowledge, organization and also introduction of new processes. It may be defined and qualified as the potential of the individual part of the system and also as the interrelation among the elements. In the language of complex system this property can be understood as the inherent creativity of spontaneous appearance of novel structure. Thermodynamically, information introduced in the system is the negentropy as the result of the change in the structure of system leading to the better performance [22].

4.5 Social Quality

Social aspect of the complex system is important factor to define the quality of the system. Beside the adverse effect of the system on the environment, there may be another driving force for the social changes in the region [21]. It can bring new jobs, new investment, new infrastructure and many other advantages in the region. This quality of the system must be defined as the elements of the complexity of the system. The interactions of the system with society are properties of the whole, arising from the interactions relationship among the system and surrounding. With a number of options under consideration the social element of complexity of the system will comprise integral parameters and their evaluation. The social aspect of the system includes risk of environmental changes, health and nuclear hazards and may have to deal with a compounding of complexity at different level. Also, under social constrain reflecting social aspect of complexity of system are added values which improve the quality of the human life .

5. INDICATORS

In order to develop appropriate tool for the quality presentation of complex system, it is of interest to introduce the notion of the indicators which are measuring parameters of the respective quality [22]. Before, we will introduce individual indicators the agglomeration procedure is described.

5.1 Hierarchical Concept of Indicators

As it was shown different complexity elements are expressed as the integral property of the system. For the determination of these elements respective model are used based on the mathematical description of the processes within the system.

Recently it has become necessary to make assessment of any system taking into a consideration the multiple attributes decision making method. It has been exercised in the number of cases the evolution of systems with criteria reflecting resource, economic, environment, technology and social aspect [23, 24, 25]. A complex (multi-attribute, multi-dimensional, multivariate, etc.) system is the system, whose quality (resources, economics, environment, technology and social) under investigation are determined by many initial indices (indicators, parameters, variables, features, characteristics, attributes, etc.). Any initial indicator is treated as the quality's, corresponding to respective criteria. It is supposed that these indices are necessary and sufficient for the systems' quality estimation [26].

An example of graph-representation of a 2-height pyramidal hierarchy of indices is pictured on the Fig.4.

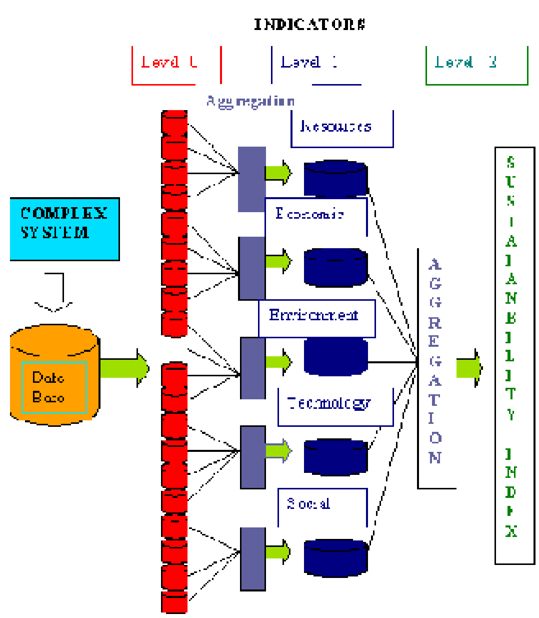

Fig.3 Graphical presentation of the algorithm for the sustainability evaluation of complex systems.

5.2 Safety Index

If it assumed that the sustainability indicator is time dependent function, we can take predefine time increment and determine Sustainability Index at the beginning and the end of the time increment. In Fig.5 is shown the block diagram of Safety Index

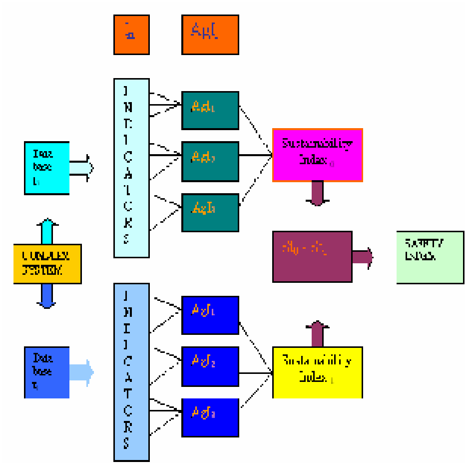

Fig.4 Block Diagram for Safety Index

In this respect we can form respective data bases reflecting individual values of the indicators for the specific time.. Following the same procedure for the Sustainability Index Increment for the specific time increment we will obtain change in the Sustainability Index as measure of the Safety Index. If this procedure will be applied for the different time increments the results obtained will give us possibility to justify Safety index as the property of the complex system. Introduction of block diagram is aimed to show the procedure for the definition and determination of the safety index. As it can be noticed the first step in this procedure is to define an increment of time for the collection of the basic data to be used in determination indicators. The safety in complex systems is an open question. We have described one approach to achieving this goal that has been demonstrated on several real systems, including :energy environment and water systems [28]. Safety, however, is not something that is simply assessed after the fact but must be built into a system. By identifying safety-related requirements and design constraints early in the development process, special design and analysis techniques can be used throughout the system life cycle to guide safe software development and evolution.

CONCLUSION

As the conclusion of this paper it can be emphasized following :

- it was shown that the sustainability index is the relevant property of the complex system to be used in evaluation of complex system
- definition of the sustainability index as the economic, environment, technological and social quality is verified as the property of the system
- the time change of t sustainable index is verified as the potential tool for the safety index for the system under evaluation

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