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HCI-enriched approach for DSS development: the UP/U approach

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Abstract

In this paper we propose an approach aiming to integrate Human-Computer Interaction (HCI) aspects in decision support system (DSS) development. We propose an approach combining two methods: one issued from software engineering field (the Rational Unified Process) and the other one from the HCI field (the U model). We have tested our approach in a DSS set up in the healthcare domain: the supervision of nosocomial infections in an intensive care unit.

Key words: *Decision Support System, Human Computer Interaction, Software Engineering, Unified Process, U model.*

1. Introduction

This paper comes within the scope of researches on Decision Support Systems (DSS) development. The evolution of data processing, the nature and the increasing complexity of the tackled problems have brought out new social, technical and political realities. In this context, the companies are adopting more and more technological solutions in their decision process strategy. The decision-making allows choosing between various possible alternatives to solve a problem by selecting the best solution or compromise. The DSS deals with the problem according to the human knowledge and aims to help users in the DSS process from beginning to end. So the Human-Computer cooperation is essential throughout the decision process. It consists in sharing tasks between the human and the computer and defining "Who does what?". In this way, the Human-Computer Interaction (HCI) is a crucial aspect for the interactive decision support systems and its design leans on a user-centred approach. The evaluation of HCIs allows validating the quality, the usefulness and the usability of the support systems. In this scope we propose to combine and integrate methods coming from Software Engineering

(SE) on one hand with methods coming from HCI on the other hand, in order to accurately design a DSS. SE lifecycles aim to improve reliability, evolution capacity, re-usability and portability of software. However these models are often limited when the studied system is highly interactive because they do not implicate explicitly and systematically the user [10]. For several years, several researchers in the HCI field have worked on the enrichment of software lifecycles by considering the human participation [10]. It seems also possible to propose adapted DSS development approaches combining both fields: SE and HCI.

The second section starts with a brief state of the art about interactive DSS. Then in the third one we present an overview of the most common development processes, in the field of SE as well as in HCI. In the fourth section we present our approach that takes advantage from the contribution of each field (SE and HCI) for DSS development. The last section lays out an application of our approach in the healthcare domain in which Intensive Care Unit (ICU) physicians have to supervise nosocomial infections.

2. Interactive Decision Support Systems

Simon [22] stipulates three phases in the decision-making process: (1) **Information research**: the identification of the problem requires looking for the relevant information according to the user's needs. This phase leads to expressing the problem to be solved; (2) **Design**: i.e. creation, analysis and development of potential solutions; and (3) **Choice**: the user has to decide among the different solutions identified. This phase includes the research, evaluation and recommendation of the appropriate solution(s).

We consider the interactive DSS like systems which, through a human-computer dialogue, one or several users have to identify, study and solve problems. The concept of interactivity in a DSS returns to the essential

part of the human in its operation, non-passive part which underlies the term "Decision-making support", but also to the quality of the integration of the various components of the system and to the nature of the HCI playing the part of the decision maker's assistant.

It is a question of designing a cooperative system allowing an evolutionary distribution of skills between the user and the computer (dependent on the problem to be solved) and offering a good integration of the two types of actors (human being, computer) in the decision-making process [11].

3. Development approaches

Finding the appropriate DSS development process is the main topic of this paper. For this reason, a critical recall of the most traditional development models proves to be necessary (we mainly focus our study on the available models in SE and HCI, the DSS field being poor on this subject) [14].

3.1. Development models provided by the SE

The software development models allow indicating the logical or temporal order in which the stages of the software production occur. Several models (and variants) are available.

From the SE field, we can talk about some traditional and recent development cycles such as the **waterfall** model [20], the **V model** [17], the **Spiral** model [4], or also the **Unified Process** (UP) [7, 9]. These models aim at the production of quality systems. But the most traditional models are too often directed towards the technical part and not towards the user, except for UP, until a certain level. For this reason, we focus on the Unified Process (UP) which is based on a specific methodological process. It is (1) based on the use cases representing the functional needs of the system, (2) architecture centred, which provides the structure that will be used as framework to the work carried out during iterations, (3) iterative and incremental; it reduces the complexity by controlling it. A project can be also seen as split up into under projects which each of them represents iteration. The iterations indicate stages of the activities sequence, while the increments correspond to stages of the product development.

The aspects of modelling in analysis and design are based on **Unified Modelling Language** (UML) [12, 19]. UP includes 4 phases: (1) the initialization to define the extent of the project and the feasibility study; (2) the development to define the needs and specify architecture; (3) the construction during which the software is built by means of several iterations and various versions of the system; (4) the transition to deliver the system to the end-users with the setting into

service and to train and support them [7, 12]. However, Lemieux and Desmarais showed many limits of UP concerning the taking into account of the end-users [13]. Considering the development of an interactive system, the characteristics of the user must be strongly taken into account. Insofar as the development processes from SE are considered to be insufficient for the taking into account the user, there was an improvement of traditional models under the HCI angle, which is the subject of the following section.

3.2. HCI-enriched development models

The improved models under HCI consideration add concepts missing in the SE models [10] such as the human tasks modelling, the iterative development by building up prototypes and the interactive system evaluation. Among these models, we can quote the **star model** [6], the **improved V model** [3], or also the **U model** [2,14,19]. These improved models show evolutions brought by the HCI to the SE. Nevertheless, none of these HCI-enriched models is perfect. Some of them present insufficiencies, such as the iterative development which can remain limited. As a result, we can note that no model makes equivalence between the advantages of the SE models and the HCI models. Moreover none of these improved models is directly linked to DSS. So, we suggest integrating at the same time SE and HCI dimensions. Under this angle, we have chosen the UP (SE model) in the precedent section. It is time now to choose a HCI-model. In this context we opt for the U model because it allows placing fundamental stages necessary to the design and the evaluation of interactive systems. It is a model which can be adapted according to the application characteristics and which already showed its applicability in various complex fields (air control, chemical, railway applications...) [10]. The U model is structured in two phases: (1) **a descending phase** of interactive system specification and design which leads to implementation; (2) **an ascending phase** made up of the system evaluation, according to effectiveness and ergonomic criteria. The validation consists in comparing the model of the prescribed (theoretical) tasks, obtained in the descending phase, with the real tasks discovered in the ascending phase (according to the original principles suggested by [1]). The result of this confrontation permits either to validate the interactive system or to demonstrate its deficiencies and then to refine it gradually. The final model resulting from the assessment allows the users' specific behaviors to be generalized under particular work conditions, and can be reused in situations dealing with similar systems [14]. The U model can be adapted according to the application characteristics; e.g., in

[14], it was adapted for particular types of DSS in projects where the elicitation of the experts' expertise is central. This elicitation aims to design corresponding software components aiming to assist the expert activities. This model is centred on HCI aspects; nevertheless, it does not present clearly the iterative and incremental development of the interactive system to be realized.

4. Proposed Approach: UP/U

The interactive system design as it is done in HCI and the processes from SE are generally carried out separately. And when collaboration exists, it is essential to study the points of anchoring privileged between the practices of the HCI and those of the SE [5]. So we propose the participation and the linking of two models of both fields (HCI and SE): the U model and the Unified Process (UP), two models which are complementary according to us. In fact, we present three points of complementarities between UP and the U model: (1) the UP is generic (as explained above). However, the U model is specific for interactive applications, it is enriched from the HCI point of view; (2) UP is iterative and incremental, based on the use cases, and thus the users needs, centred on architecture but not on the user. Nevertheless, in the U model, the human factors are taken into account by the development team; it is user centered (the confrontation between theoretical and real tasks for the validation and the refining of the system); and finally (3) the design activities of the UP can be enriched by the design activities of the U model under the HCI angle. So, the development approach we propose must allow: on one hand to take into account the user (contribution of the U model) and on the other hand to focus on the prototyping, the explicit positioning of the actors' activities in the development process and the analysis of the activity (contribution of the UP).

For the DSS modeling, we use **UML** [12, 21]. In fact, UP is based on UML [7]. In addition, it is a language that allows models to be represented without defining their development processes. So it can be used transparently with any other software development process, allowing using this language with the U model that does not define an obligatory modeling language.

4.1. Development Approach

For highly interactive DSS, we have adopted the U model, which needs to be adapted to the UML context to be used for DSS development [15].

Adaptation of the U model. Why shall we modifying the U model? The U model splits up into several stages which clearly show the integration of the HCI in the development process. Nevertheless, this

model can be adapted in our context. Thus, when the existing system is studied, it is important that the decision maker (potential user) describes his/her functional needs and evaluate and validate the first HCI versions (mock-ups, prototypes) in order to show the way he/she wants the future application interfaces to be. All this information can be used "to model" the decision maker (characteristics, preferences, strategies...) [20]. Moreover, for the DSS, the definition and the allocation of the tasks are very important and must be well defined. The initial U model [2,14,18] does not clearly present the order of the design activities (needs assessment, analysis, design...). We think that such a precision is necessary to use the U model with UP. The stages of U model are generally interested in the specification and the evaluation of the HCI but do not mention much about the applicative side of the interactive system, whereas this aspect is significant for the DSS. The adapted U model is presented in figure 1. Its description is as follows.

Descending phase [15]: this phase starts with two essential simultaneous stages that show the beginning of the project: (1) the analysis of the application field generally allows the first functional and structural description of it; (2) as soon as possible in the project, we have to build first prototypes to imply rapidly the future users in giving them an outline of possible solutions. These two stages are designed to provide a structuring framework, with regard to the future activities as well as the technical solutions. After these two stages, a definition of a process model of work is issued (figure 1). That allows to define the list of tasks to be carried out for the operation of the future DSS to realize. They can correspond to functional and non-functional needs: for example, the need to make the use of the DSS very easy corresponds to a non-functional essential need. Preceding work can be cyclic, as the arrows suggest it on the model. The prescribed tasks following the execution of the preceding stages must be modelled [1]. One uses UML to define the tasks through use cases diagrams with their detailed description. Following the use cases construction, it is necessary to carry out the tasks-oriented analysis and design both in terms of HCI and applicative aspects. Each task in the interactive system has a degree of interactivity. Three main categories of tasks can be identified (these categories are traditional in SE and HCI since the Eighties): (1) the tasks in which only the user is implied, called **manual** tasks, (2) the tasks in which only the applicative aspect is implied, called system or **automatic** tasks, (3) tasks implying both the user and the system, called **interactive** tasks. The UML

collaboration and sequence diagrams allow specifying and designing the HCI for each task (while associating these models increasingly precise representations in terms of screen pages). In that purpose, we have to refer to the probable behaviours of the various types of user: it corresponds to a user model in the large sense [20]. Some knowledge on the users are general and come from the literature, others are specific and come from the field (interviews, observations...).

According to the field specificities, it is a question of analyzing the various tools for Decision Support (DS) in order to define the most adapted ones to the context of the system to realize. The last stage of the descending phase leads to the implementation of the complete DSS or its prototyping. This stage of implementation transforms the concrete HCI characteristics in a representation that can be implemented directly by using a graphic toolbox or a HCI generator.

Ascending phase [15]: the evaluation of the interactive system consists in testing if the users can achieve their tasks by using it. Two properties are usually explored for such evaluations: utility and usability, themselves divided into a whole of well-known criteria in HCI. There are a great number of methods usable for HCI evaluation [23]: observations, interviews, traces analysis, questionnaires, etc. In this phase, we generally concentrate on the execution of the tasks linked with the visible elements of figure 1: (1) on the one hand according to the user behaviour during the interaction with the system (difficulties, necessary time to achieve a task, numbers and types of human errors, etc), (2) and on the other hand, according to the system in terms of differences between the objectives and results obtained. This ascending phase starts with the rigorous definition of the experimental protocols (subjects, situations and tasks concerned, implied HCI and assistances, data to collect...) [2]. Once collected, the data is treated according to the worked out operational principles of the preceding stage. It is a question of correlating the data obtained with the human activity which was observed, and this for the unit of the decision-making process. Operating sequences are thus showed. This work allows gradually reconstituting the real tasks. Experience shows that these tasks can be very different from the prescribed tasks (initially described in the descending phase). A fundamental principle of the U model is precisely the confrontation between the real tasks and the prescribed tasks. The result of the confrontation leads, either to validate the complete system (HCI and support), or to reveal its limitations to improve it gradually. Feedbacks towards various stages of the descending step are thus

necessary, according to the extent of the improvements to be brought to the system.

4.2. Total methodology suggested (UP/U)

The HCI has a dominating place in our approach which aims at the realization of DSS. The approach that we propose (figure 1) redefines the user role so that he/she can intervene at any time of the decision-making process. To do so, we used the principle of iterative and incremental development of UP, that allows an early evaluation of each task carried out from the first iterations of the development process. So our approach consists in proceeding in several iterations from inception to the transition. We have applied the adapted U model in each iteration. In fact, the five activities of the original UP (needs assessment, analysis, design, implementation and tests) model neither the users nor their interactions with the machine. Our approach thus recommends the presence and the constant user participation throughout the project. The objective is to get the interaction between the user and an intuitive, ergonomic and adapted DSS in order to increase the effectiveness of the human-machine couple and to prepare, as soon as possible, the acceptance of the system by the users. In figure 1: A, B, C, D and E are the new activities of UP. Each activity is divided into sub-activities that model the HCI of the aimed DSS.

5. Application in the healthcare domain

In the preceding section we presented our global solution for DSS development. This approach was applied to a concrete case in the healthcare domain. It aims to help physicians (users of the system), to understand and prevent nosocomial infections (i.e. infections contracted by the patients during their hospitalization). It is currently under use in the ICU of the Teaching hospital Habib Bourguiba in Sfax, Tunisia. The design and the realization of this DSS were carried out according to the four phases of UP (inception, development, construction and transition). Each stage of these iterations (needs assessment (A), analysis (B) and design (C), implementation (D) and test (E)) was carried out while following the actions suggested in the U model (figure 1) (needs assessment, definition of the tasks, users modeling, and prototyping of the interfaces and application, evaluations and validations). These actions are not carried out with the same "intensity" in each iteration. Let us take the example of the action "user modeling"; this action began "quietly" at the beginning of the project (phase of inception of UP), became dominant from the first iteration of the development phase, it is reduced to almost nothing at the last iterations of the construction

and transition phases. At the moment we are testing the 9th version of the application. This gives an outline of the difficulties related to this application field, and especially of the need to go ahead step by step in very close link with the users suggesting gradually of new

improvements and tests, within sight of the results obtained at the time of the preceding iterations. Because of the lack of place in this article, it is not possible to explain each implementation step of the suggested approach, but that will be the subject of future articles.

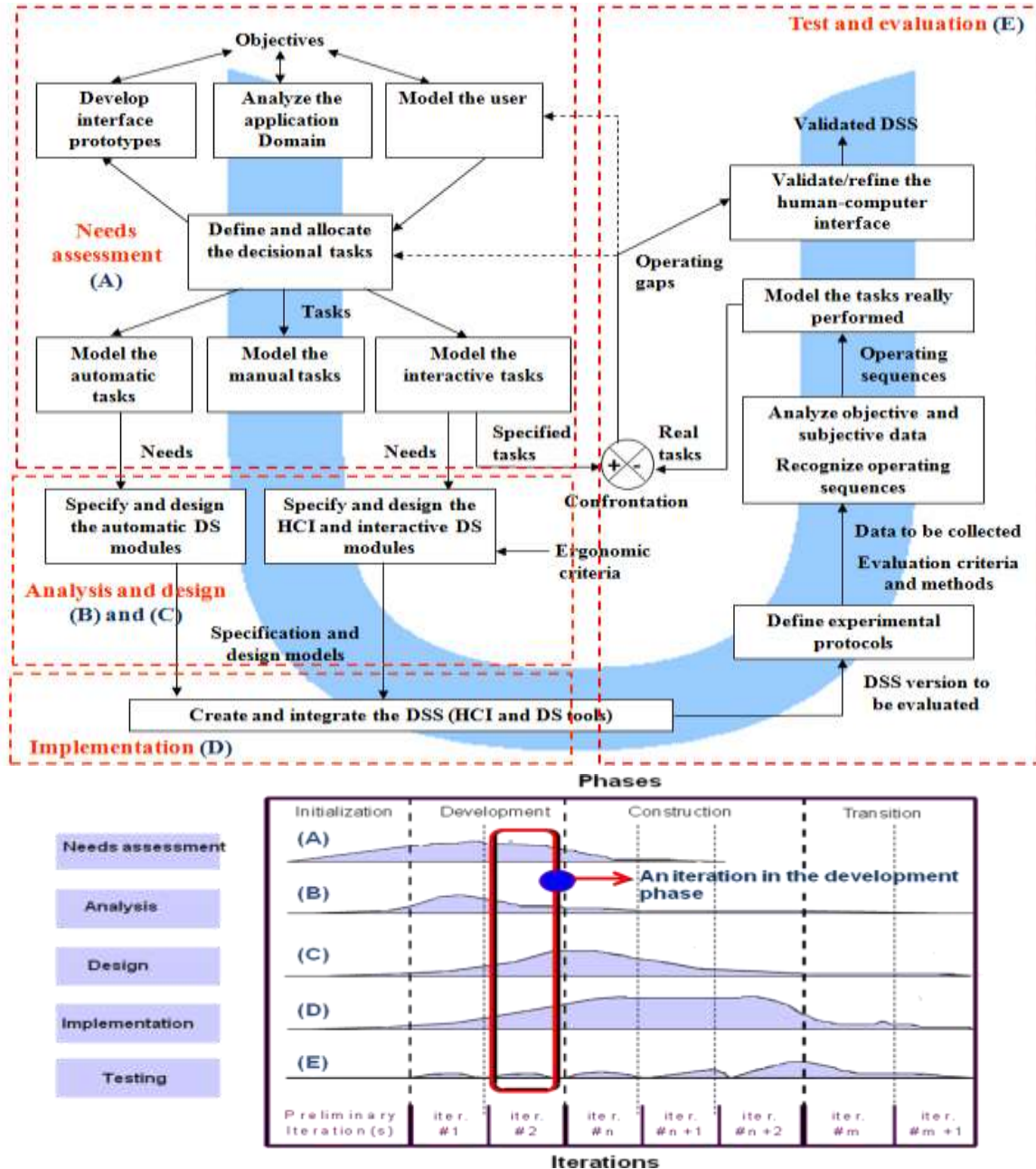


Figure 1: the UP/U approach

6. Conclusion

This article is the result of a work proposing an HCI-enriched approach for DSS development. We are

interested in highly interactive DSS. Indeed, the decision-making requires a Human-Computer Interactivity to be carried out. A modelling of such a system must thus call upon two specialities: SE and

HCI. That is why we propose an approach using the U model coming from the HCI field, and UP methodology coming from the SE one. They are complementary; so it is possible to carry out a DSS that takes advantage from the two fields. In order to validate this approach, we currently develop a DSS in the healthcare domain. This system aims at the supervision of the nosocomial infections, contracted in a hospital Intensive Care Unit. The realization of the project is done in constant connection with the physicians, users of the system: needs assessment, tasks definition, identification of the users' characteristics, and prototyping, evaluations and validations with them. The finalization of our DSS is not totally completed. Further works will be held to improve and validate it. We also intend to use techniques of data mining to extract knowledge from data. Knowledge resulting from each of these techniques helps users to make decisions. We also wish to propose a methodology for the evaluation of DSS taking into account the methods and techniques of evaluation used in two fields: HCI and visual data mining [8] [16].

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