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INTEGRATION OF COGNITIVE ERGONOMICS CONCEPTS IN KNOWLEDGE BASED SYSTEM DEVELOPMENT METHODOLOGIES

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Abstract: A Knowledge Based System (KBS) has to permit to one or more users, generally not experts, to solve problems concerning of human expertise. Present KBS development methods help designers to define systems which correctly function from expert competence point of view, but which have important deficiencies from interaction point of view with users. This paper presents basis of a methodology which views at once a co-operative approach between expert, user, computer engineer, human factors specialist and knowledge engineer for development of acceptable, useful and usable systems.

Keywords: Human-centered design, Knowledge engineering, Interactive approaches, Co-operation methodology, Human factors.

1. INTRODUCTION

At present, the problem of users and Knowledge Based Systems (KBS) interaction comes up in a crucial way since, among the available systems, few of them are really used. Indeed, in most of applications, KBS are only developed from experts knowledge, and end users are only considering during system integration within its environment (Mc Graw 1993).

In first part, the knowledge acquisition will be presented as a model-building approach including both elicitation and analysis. Considering this approach, it may be pointed out that expert reasoning acquisition remains one of the prominent aims of knowledge engineers. However, our attention will be devoted most particularly to the participation of KBS users throughout the developing process. Actually, it has been demonstrated by many authors that by taking human factors into account and by setting a participation approach, KBS integration in the Man-Machine

system is thus made easier, thereby improving most particularly its operative ergonomics. Therefore, in second part, a system development cooperative methodology is proposed. Third part of this paper presents an industrial example about the use of this methodology.

2. KBS METHODOLOGIES

2.1. Knowledge acquisition

The outcome of a Knowledge Based System (KBS) development project depends most of all upon the initial knowledge acquisition phase (Gaines and Shaw, 1993). As a matter in fact many studies have been aimed at improving knowledge acquisition process. Thus, knowledge acquisition no longer tries to be passed on directly from expert knowledge right to an implemented representation, but rather to formulate an intermediate expertise model, followed later on by its implementation (Johnson, 1988; Wielinga, *et al.*, 1993). While knowledge elicitation techniques are now reported to be under control, the

expertise modeling phase is still deeply complex (Krivine and David, 1991).

Human sciences contribution is important to outcome a project which aims to model and broadcast experts knowledge. Cognitive ergonomics, which deals with study about interactions between human and its environment, constitute a preference inspiration source for designers. This induces to present the cognitive ergonomics intervention in KBS development.

2.2. Cognitive ergonomics intervention

The cognitive ergonomics intervention could be examined on different levels as displayed by the examples hereafter, according with acceptability, utility and usability criteria (Nielsen, 1993):

- **knowledge elicitation:** the human factors specialist makes use of theoretical knowledge relative to mental processes as well as tested methods to report on the knowledge elicitation phase, mainly resulting from work analysis methods (i.e. task and activity-based analysis). Concerning this topic, presently active researches in cognitive sciences, but also in software and human engineering about human tasks analysis have been brought to the fore. Some graphical methods among the presently most famous and most used which aims to model them could be quoted: GOMS (Card, *et al.*, 1983) and its recent variations (John, *et al.*, 1994), SADT/Petri Network (Abed, *et al.*, 1991). Such methods are very useful in order to specify KBS which really are centered on users tasks.

- **ergonomic specification and evaluation of Man-Machine interfaces:** during the determination of the interactions between KBS and its users, the human factors specialist is an essential contribution to their specification as well as their evaluation. To illustrate this point, in the field of ergonomics literature, hundreds of recommendations are made aiming to the improvement of Man-Machine interfaces (Smith and Mosier, 1986; Schneiderman, 1987; Brown, 1988; Scapin, 1990). It may also be noticed that it is essential for ergonomic interface development to use a KBS potential user model. Indeed, even though expert knowledge constitutes the KBS base, it is nonetheless necessary to consider the subsequent use which will be made. This model will be found again in the methodology which is proposed below. Concerning KBS evaluation, richness of available methods have had been insist on. Classifications of interactive systems evaluation methods could be seen about this topic (Wilson and Corlett, 1990; Senach 1990; Sweeney, *et al.*, 1993; Grislin, *et al.*, 1993).

- **following on-site installation:** the human factors specialist should analyze the possible constraints resulting from KBS (that is: work organization and tasks divisions) to quote but a few of them and as a consequence should propose adequate improvements. The previously quoted tasks modeling methods will have a great importance, since they will permit to compare theoretical tasks model (which is define during prior analysis) with real model of KBS user activities. This comparison allows to put in light problems which concerns its usefulness and usability (Abed, *et al.*, 1991; Millot and Roussillon, 1991).

Then, this set of observations induces us to bring to light the dependency between knowledge engineer and human factors specialist. Indeed, the knowledge engineer, together with the human factors specialist is to analyze the user's needs while taking the user's abilities and knowledge as well as the final system facilities and limits into account.

3. INTERACTIVE METHODOLOGY FOR KBS DEVELOPMENT

The proposed methodology aims to give some answer elements to the sensitive problem concerning KBS integration within its operational environment with a great attention to end users expectations.

This methodology, covering the whole KBS development life-cycle describes the necessary activities to define:

- **the expertise model** to acquire and characterize expert knowledge.
- **the use model** to take the user's needs into account in order to specify Man-Machine interfaces.
- **the organization model** to take operational environment of the final system into account.

3.1. Tridimensional life cycle

These three activities are integrated in a life cycle which organize the different KBS development phases, as shown in figure 1. This development is composed of the five following phases:

- *Problem analysis* which leads to a book of requirements. This document, which is established from client's needs, points to the problem to solve and expectations in terms of results too.
- *Specification* which elaborates a detailed conceptual solution independently of any development means, based on the book of

requirements. Specification is split up in three analysis facets: **expert knowledge analysis**, **physical environment analysis**, and **use forms specification**. The expertise model itself is completed by two models characteristic of system cooperation form with the user. They are organization model and use model.

• *Design* phase associates these three models with a view of describing future system functionalities, that is identify the main knowledge modules and their inter-relations but also define the user's interfaces.

• *Implementation* define possible solution from organization and real characteristics of software and hardware. Modules are gathered to build the final system.

• *Exploitation* confronts system and maintaining operations which integrate debugging and concern KBS evolution too.

Validation is made all along life cycle and constitute by itself a current research topic (participate process,

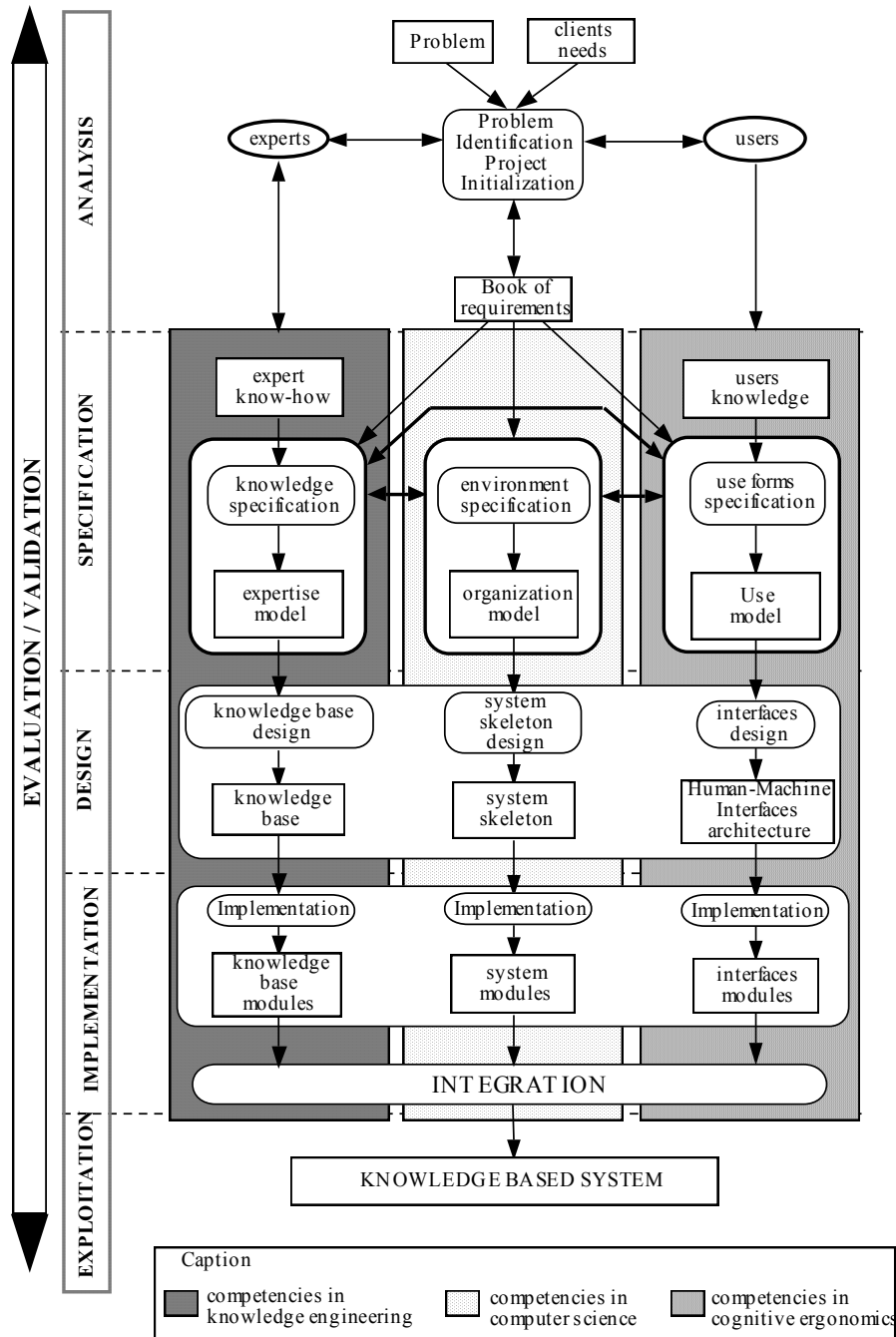


Fig. 1. Tridimensional life cycle

prototyping, analytical evaluation methods,...). Cf CACM (1993).

As shown in figure 1, KBS development requires three types of competencies marked in cycle by columns with different gray levels:

- Competencies in knowledge engineering to elicit and analyze expert knowledge in order to build knowledge base.
- Competencies in cognitive ergonomics to take future use system into account.
- Competencies in computer science to allow KBS kernel elaboration and system integration within its physical environment.

3.2. Actors involvement in life cycle

KBS development requires now the participation of actors with varied competencies and interests instead of two main interveners like before (expert and knowledge engineer). Particularly, experts and knowledge engineers, users and human factors specialists, and computer engineers are concerned in turn during different life cycle phases (figure 2).

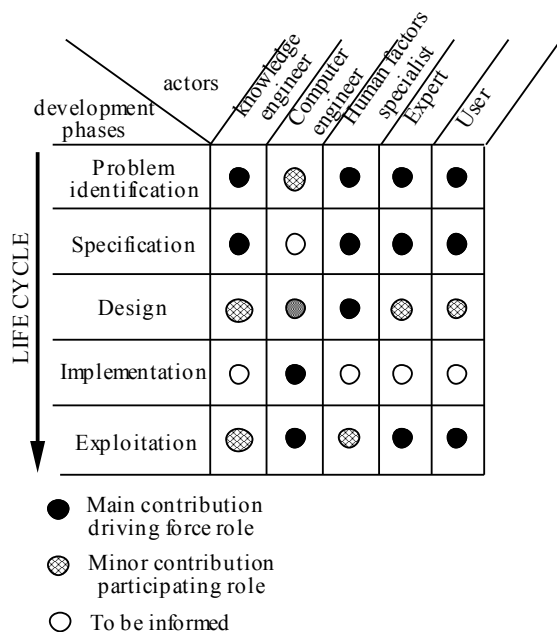


Fig. 2. Actors and life cycle phases

In KBS development, three types of specialists are distinguished:

- knowledge engineer who competencies are close to human sciences (psychology more particularly) elicits and analyses expert knowledge, elaborates models.
- Computer engineer, who masters computer and artificial intelligence techniques, defines trends for physical development and concretizes system by implementing different modules.
- Human factors specialist who analyses and/or anticipates user-system interactions forms,

analyses user needs, follows their evolution and manage adaptations until system exploitation.

In order to evaluate this tridimensional life cycle, this methodological framework was tested on a real application.

4. INDUSTRIAL APPLICATION

During its activities, the L.A.M.I.H., in collaboration with SOLLAC steel works of Dunkirk and IRSID (Institut de la Recherche et de la Sidérurgie Française), developed a knowledge based system dedicated to help in the diagnosis of defect causes on steel rails (blooms) and plate made in the steelworks (Benkirane, *et al.*, 1991).

The setting up of continuous casting of steels produces blooms, about ten meters long, about one large and half a meter thick, from melted steel (figure 3). These blooms are later re-used through a rolling mill with the aim of its transformation in plate.

This type of installation can be the cause of quality problems. Indeed, according to the blooms format, melting steel quality, process supervision parameters, the users are sometimes faced with an epidemic occurrence of surface aspect defects or/and inside the blooms. The latter, observable on blooms or revealed on plates after lamination, impair the productivity (repairs on blooms and/or plates, scraps, manufacture stimulation ...) and come from causes sometimes difficult to identify.

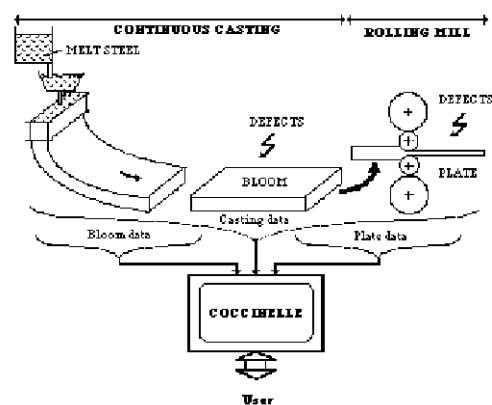


fig. 3: The process of blooms and plates fabrication

The main difficulties met to make a diagnosis result from the gigantism of the installations and from the wide range of semi-finished products. These various factors of the expert in front of a very large quantity of information, widely spread in time and space. It is in this context that the LAMIH, with the help of experts in continuous casting of SOLLAC steel works of Dunkirk and IRSID, designed and realized the "COCCINELLE" system.

The KBS development follows the sequence of phases shown on figure 1. This article focuses on the specification phase with the elaboration of the expertise model, the use model and the organization model.

4.1. Expertise Model

Expertise model framework is based on KADS model (Wielinga, *et al.*, 1993) which considers differentiation between knowledge types according to three levels:

- *Domain level* contains domain elements which are concerned by the problem.
- *Inference level* describes functional point of view about this domain knowledge.
- *Task level* specify goals and the way to organize and control reasoning steps to reach these goals.

The obtained model simultaneously contains a specification of problem solving method as well as a domain knowledge organization, which depends on their function in solving process.

In COCCINELLE application, expert reasoning is done through three steps which are put in light in inference structure presented in figure 4:

- Identify population at the origin of crisis (component) from noted defect (problem)
- Specify crisis characteristic clues (symptoms)
- Generate a list of probable causes of these defects (diagnostic).

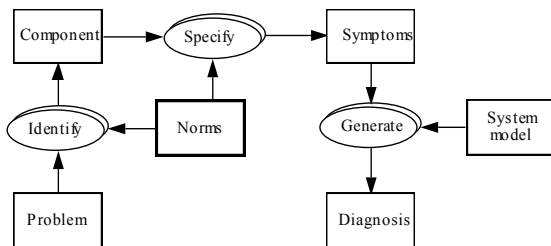


Fig. 4. Inference "diagnose causes"

4.2. Organization Model

Organization model specifies system function, how it is split up into tasks and sub-tasks by expert. The SADT method (Structured Analysis and Design Technique) (Ross 1977) is an important contribution to elaborate this model. On the one hand, it represents system functional hierarchies and data flows. On the other hand, it simplifies communications between expert, knowledge engineer and computer engineer.

The actigram in figure 5 describes system global function and its decomposition into three sub-tasks. It permits to:

- Distinguish different modules which split up the system.
- Visualize clearly tasks management .
- Point out the user type for main system tasks. In the example, to realize detection and crisis description tasks, the consultant has to be an expert. Effectively, expertise lies in the choice of significant rates to characterize crisis.
- Present technical constraints of system integration in its environment such as the necessary link between system and site production data and the requirement to dispose of reference thresholds which are characteristic of firm know-how.

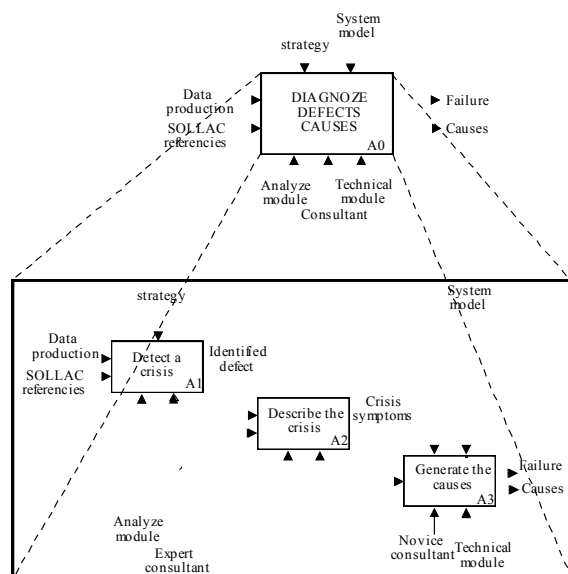


Fig. 5. Actigram of the two first application levels

4.3. Use model

Expert knowledge make up KBS base but they do not generally take use into account. A cognitive approach, similar to expert knowledge elicitation, allow to consider users' needs.

The cognitive ergonomics role is to disclose knowledge on users' needs and describe knowledge domain and expertise level from user point of view. User activity analysis takes human factors into account in order to characterize working habits, users' needs and technical constraints. The simulated putting in situation of expert and user problem solving, for instance with "wizard of Oz" technique (Salembier 1991), generates dialogues which are recorded and then analyzed. Knowledge engineer, in collaboration with expert, is able to propose situations bringing into play problem types. Then, human factors specialist studies interactions and assistance types.

Scenarios simulation give the advantage to elicit information both user and expert. From user point of view, simulation permits to study needs in terms of information type and nature and to specify his competence and understanding levels in domain. From expert point of view, simulation puts in light aid type which expert introduces in problem solving, tasks sequence according to simulated problems, explanation levels expert bring either to guide solving method, or to give precision about solving, or to clarify misunderstanding points. This simulation gives occasion for knowledge engineer to evaluate knowledge level difference between expert and user.

Elaborate use model consists in rationalizing and organizing the obtained results during simulation to describe the way by which a end-user has to represent himself system functioning. To be consistent with expertise model, use model have to keep same organization, i.e. KADS formalism:

- *domain level* puts in relation users domain knowledge with expert's one (own user terminology, synonymous, data presentation symbolic such as textual comments, graphical objects, ...).
- *Inference level* describes modifications to bring expertise model inference level in order to take users competencies and goals into account.
- *Task level* take users competencies into account navigate within previous level. Each task is described with its goal, its control and presentation constraints. Explanations about taken decisions and obtained results after solving are conceivable at this level.

5. CONCLUSION

In synthesis, a KBS development methodology is proposed here, not involving expert reasoning but also:

- Taking the final system operational environment into account.
- Setting up a coherent dialogue with the user by using particularly suitable vocabulary.
- Generating explanations suited to different types of users.

Thus, KBS development should take knowledge engineering into account as regards knowledge acquisition as well as cognitive ergonomics as for the final system adaptation to the user. In both disciplines, the former conditions KBS quality while the latter is essential for the acceptance of the system by the user.

COCCINELLE is now using in industrial environment. This shows the system responds to users expectations and that our co-operative

methodology which is the base of the development of COCCINELLE is validated.

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