Artificial intelligence approach for the creation and the ergonomic design of man-machine interfaces in control room

Faouzi Moussa, Christophe Kolski, Patrick Millot

In: Ninth European Annual Conference on Human decision making and manual control, Varese, Italy, september, 1990.

ARTIFICIAL INTELLIGENCE APPROACH FOR THE CREATION AND THE ERGONOMIC DESIGN OF MAN-MACHINE INTERFACES IN CONTROL ROOMS

F. Moussa, C. Kolski, P. Millot

Laboratoire d'Automatique Industrielle et Humaine, URA CNRS N°1118 URIAH
Université de Valenciennes, Le Mont Houy, 59326 Valenciennes cedex, FRANCE
Phone: 27-14-12-34 Fax: 27-14-11-00 Telex: 810270F

ABSTRACT:

This paper presents our current research regarding the study of an Artificial Intelligence approach for the design of graphical interfaces in the domain of continuous complex processes. Thus, this paper presents the structure of an expert system composed by the chaining of several modules, each performing an accurate task in the ergonomic design of graphical interfaces. In fact, in every module, several techniques of representation and exploitation of knowledge are used (production rules, semantic networks and frames). A brief description of the three main modules composing the expert tool for designing man-machine graphical interfaces is presented in this paper.

I - INTRODUCTION

The technological evolution in the continuous industrial processes is characterized by the installations increasing complexity, the control and supervision process centralization and the computer more and more frequent use in order to control this process. Thus, the current trend, in the control rooms of automated processes, is the information presentation on graphical display screens. For this purpose, many tools of graphical edition have appeared to cater for industrial synoptic designers needs. Then, lots of ergonomic problems inherent in the use of graphical displays in control rooms appeared. These problems can result from gaps in the way of presenting the graphical data on the screen. This is often due to the fact that the designer has - in most of the cases - little or no ergonomic knowledge. Therefore, an ergonomic corrective method has to be implemented so as to improve the data presentation. The expert system SYNOP developed by Kolski (1989) - helping the ergonomic evaluation and improvement of the data presentation - helped studying the corrective ergonomic notion thanks to formal techniques, and stressing a few limits of such a corrective ergonomic process. But, these ergonomic problems may also arise from gaps in the analysis of the operator informational needs during his different tasks. Moreover, the data on the screen, meeting the needs, can also be misdistributed on the different displays which form the graphical imagery. After a dynamic evaluation of these displays on the site or in simulation, it's important then to verify the synoptic structure itself and to come back to an ergonomic design stage. The insufficiency of formal processes in this field underlines the interest of present researches concerning the study of ergonomic design method based on the processing formalization of ergonomic knowledge.

To begin with, this paper briefly presents the expert system SYNOP. This system is integrated in a global ergonomic methodology of graphical displays design, and is based on a formal approach of corrective ergonomy point. Then, the paper describes our first research works concerning the study of a new ergonomic design methodology based on the model of an expert system of ergonomic design.

II - FORMAL METHOD OF CORRECTIVE ERGONOMICS: APPLICATION TO THE EXPERT SYSTEM SYNOP

In order to take into account the human factors while designing the graphical interfaces, the helping methods often consist in the use of ergonomic guidelines such as Cakir & al. (1980), Mc Cormick & al. (1985) or Scapin (1986), or in the best case, in the consultation of an expert in ergonomics (see Lucongsang & Nouvellon, 1986). At present, tools which integrate formalized ergonomic knowledge, such as SYNOP, begin to be studied in the research laboratories.

SYNOP is an expert system, presently, under the form of a laboratory model. Its purpose is to evaluate and to improve automatically the displays and to give the designer advices, according to the ergonomic rules of data graphical display on the screen. The ergonomic rules are centralized in its knowledge bases and formalized in production rules (Kolski & al., 1988). We distinguish two types of ergonomic rules: (i) General rules dealing with basic ergonomic concepts, such as those which are related to the characters size, the use of colors and contrasts, the data repartition on the screen ... (ii) Ergonomic rules which are specific to the treated applications such as the process control, the displays embarked in the cars (Moussa & Kolski, 1989), and so on.

Developed in the LISP language, SYNOP uses several techniques of representation and use of knowledge: a first order logic inference engine (Grzesiak, 1987), frames (Minsky, 1975) and semantic networks (Bonnet, 1984). It is at present interfaced with a tool of creation and animation of graphical displays using the GKS norm. Figure 1 represents the SYNOP structure.

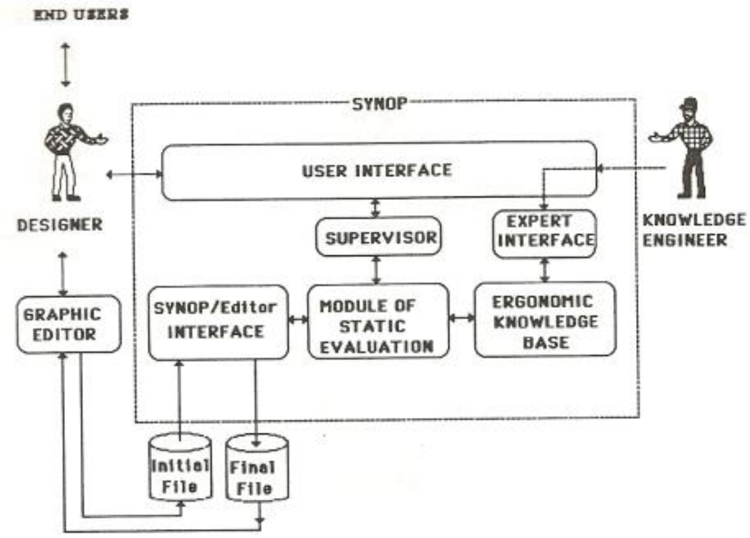

Figure 1: Stucture of the expert system SYNOP

Therefore, SYNOP includes a "static" evaluation module of graphical displays which purpose is to evaluate and correct some displays outlines. This is done according to ergonomic rules arranged in its knowledge bases. Thereby, SYNOP, as a tool of evaluation in "static", integrates in a general methodology of graphical Man-Machine interface design. This methodology is described on the figure 2 (Kolski, 1989; Millot & Willaeys, 1987; Taborin, 1989). The aim of the first stage is the selection of the set of data which are necessary to process control, from among all the available data. This set constitutes the operator's informational needs. It results from an analysis of human tasks in the different operational contexts of the process (Hollnagel & Weir, 1988; Woods & Roth, 1988), or from an analysis of the probable future activity (Daniellou, 1988) if the process is only in the stages of design. The second stage consists in defining the decomposition framework of the pictures while taking constraints imposed by the software and hardware limits of the graphic support selected for the application into account. Then the third stage allows us to obtain the synopsis schedule. This is constituted with a framework of displays deduced from the structural and functional decompositions of the operator's informational needs (Taborin & Millot, 1989). For instance, one of the displays provides the operator with a concrete representation of a cooking system; another displays the values of a temperature and two pressures. The fourth stage defines the mode of graphic information presentation for every display of the synopsis. Thus the animation functions are selected, placed on the screen, associated with a static graphic environment, color coding, etc. The fifth stage consists of the graphic creation of the displays for instance by means of an editor of animated graphic control displays.

Then an ergonomic evaluation aims to insure that the created displays answer the informational requirements of the operator. This evaluation can be divided into two stages: the "static" and "dynamic" ones. The "static" stage's objective is to verify that the displays respect ergonomic rules of information presentation on a screen. It is necessary to apply a set of ergonomic criteria related to the human information acquisition capacities. These criteria concern especially: the accuracy of the representation modes chosen for each piece of information; the shape of the different symbols used to represent the components of the process; for instance: specific colours for specific types of information, contrasts between these colors (Murch, 1984), the localization of the different items composing each display, and the arrangement of the windows on the screen. The ergonomic criteria applied are generally expressed in terms of rules in design guidelines. However if numerous rules are general ones, some are specific to a particular industrial area. This is the case of the nuclear area where specific design norms must be applied (Taborin, 1989). Presently, research works tend to define methodologies or create tools with a view to fostering a better consideration of these criteria for designing the synopsis (Fassote, 1986, Elzer, Borchers et al., 1988; Kolski, Tendjaoui et al., 1990). The expert system SYNOP intervenes in this stage. The "dynamic" stage is carried out on the industrial site and/or in simulation. Its principal aim is to verify that the structure and the content of each display responds to the operator's informational needs during the execution of his tasks and according to the different contexts of the process. There is currently no particular method to carry out this evaluation, although some general ones can be used: subjective methods like questionnaires, or more analytic ones like cognitive task analysis methods (Woods et al., 1981; De Keyser, 1988) which consists in dividing supervisory tasks into objectives and sub-objectives and in verifying that the content of the displays allows the operator to reach them.

These two ergonomic stages lead either to a validated interface or to being sent back to the previous stages for improving the final system, figure 2.

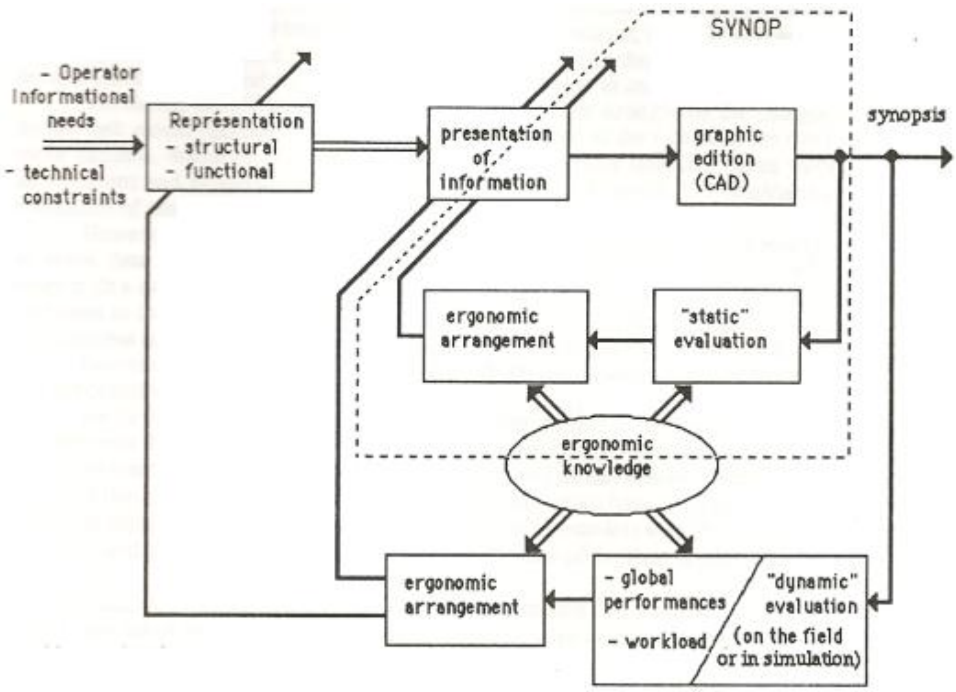

Figure 2: Ergonomic methodology for man-machine interface design

Although the SYNOP intervention in the static evaluation stage helps improving the data display according to some ergonomic criteria (criteria which are formalized in production rules) there are some cases for which the ergonomic rules to apply are very general, subjective, or difficult to implement. SYNOP is then unfit for automatic modifications and deals only with providing the designers with advices. Moreover, knowing that the graphical representation methods of the process different variables are chosen "à priori" and may eventually not correspond to the operational context of the application, SYNOP can not intervene to change them. This is due to the fact that it only corrects the syntactic aspect of the display, and not the semantic aspect. This restriction requires to go further and to take advantage of the acquired experience during these works of ergonomic knowledge formalization in the corrective ergonomic field, in order to move towards a formal process aiming at automating some aspects of the ergonomic design. The study of the problem in this field forms the subject of the following paragraph, which is illustrated - regardless of exhaustivity - by some recent works.

III - THE ERGONOMIC DESIGN PROBLEM

According to Scapin & al. (1988), the Man-Machine interaction is not always clearly dealt with. Indeed, these authors explain that the models which are now proposed are too general, too informal and lack - for the greatest part - organization to be directly usable by the designers. Thus, this deficiency characterizing the ergonomic models causes difficulties to computer scientists and even to ergonoms for the ergonomic recommendation utilization. Effectively, according to Scapin (1988), these difficulties are of several types, summing up numerous studies in this field. For example: (i) The interface's designer is not always in a position to allow the necessary time - which is often very long - to read completely a manual of recommendations. (ii) Recommendations are often very general and pose problems of access which are too intricate for a beginner. (iii) There are some interactions between the ergonomic criteria, leading to compromises which are difficult to estimate for a beginner. (iv) As in every fields using the exploitation of an expert knowledge, the ergonomic data do not always converge as their form and their contents change according to the design criteria (use performance, learning performance, etc.).

It is therefore necessary to collect the design general principles used here in the ergonomic field of the graphical Man-Machine interfaces. The aim of this collection is to understand better the design problem and to try to bring about formal solutions which are applied to the study and the creation of a computer tool helping the interface's design.

III.1 - THE DESIGN GENERAL PRINCIPLES: Brown & al. (1983) consider that, generally speaking, there are three categories of design: (i) Category 1: the inventive or creative design. (ii) Category 2: the special case in relation to a certain routine; if there is a potential market, the firm will generally invest in order to change the exception into a routine case. (iii) Category 3: the routine design which, given a well known problem solved several times, tries to find out an optimal function in answer to certain specifications.

Therefore, the difficulty of the design task depends strongly on the category. So, the complexity of the design task would decrease from the first category to third as the rules that are used would get less heuristic and more explicit. Whatever the category, the design, generally speaking, goes through three phases which are independent and especially not sequential: (i) Problem analysis, (ii) originating of answers, (iii) critic and evaluation of answers.

However, this approach is still not very efficient as a problem is never totally dealt with and described, and as some data of the problem appear during the design. For this purpose, Darke (quoted in Lawson, 1980) propounds a methodology which meets the prototypage method used in the software engineering: (i) Classing the problems in importance order, (ii) building a model which answers the most important problems, (iii) observing the reactions and deducing new problems, (iv) going to the first step, or stopping.

Nevertheless, the designer has still to decide on the iteration stopping so that the application does not reach too important sizes.

As for Mantalban (1987), he defines the design as such: "the design is a process which creates and solves the problems dynamically". He specifies that a problem cannot be statically stated, but that it must be considered as "in constant tension with its answer". According to Lawson's most general point of view, the design consists in saying that a designer essentially operates constraints which have three principal characteristics:

- Their generator: Lawson distinguishes four types of constraints classified here in: (i) generated by the design, (ii) generated by the customer, (iii) generated by the user of the final product, (iv) imposed by the legislation (the most rigid).
- Their field: It helps creating two categories of constraints: (i) internal: only the relations between the artefact objects are taken into account, (ii) external: relations between the artifact and its environment are taken into account.
- Their function: according to Montalban (1987), the function of a constraint depends on everyone's point of view and, is then dealt with in several proposals. However, Lawson distinguishes four of them: (i) practical: concerns the production reality, the manufacture, etc, (ii) radical: describes the object usefulness, its functionalities, (iii) formal: describes the object aspect, its form, its colors, etc, (iv) symbolic: in order to treat the object as a symbol.

In the field of the design applied to the ergonomy of the graphical Man-Machine interfaces, Scapin & al. (1988) suggest two different global stages for the development of a system: the design and the implementation. Moreover, the ergonomic design stage has to be ended far before the beginning of the implementation stage. More exactly, by relying upon some of Bailey's (1982), Hendrick's & al. (1982), Shneiderman's (1980, 1987) and Scapin's (1986) suggestions concerning the interfaces design, these authors identify some fifteen stages for the design process, going from "the identification of the needs" to "the preparation of the system future evolution". Basing themselves on this cutting out, they insist on the necessity of a modular approach according to a hierarchical structure coming near to the designer steps; which, in their opinion will allow to implement methods of design based on formal models at a medium and long term.

It is therefore interesting to insist on the fact that an ergonomic application is more than an ergonomic dialogue, and that it is effectively true that it is impossible to conceive without thinking conjointly and in interaction the user and the task, which represent the two major parts of the design process (Valentin & Lucongsang, 1987).

"The first major part" of the design process, the user, being the future "potential customer" must be considered with particular care from the starting phase of the design task (Shneiderman, 1987). Effectively, a user will be much disposed to accept a system if he has been associated to the specification step and if he notices that a certain number of his proposals has been implemented. Thus, calling for well established techniques (interviews for instance), the most experienced users can take part in the success of the final product by making sure that their requirements have been taken into account (Gould & al., 1985).

As far as the task is concerned - "the second major part" of the design process - it is particularly interesting to notice an increasing research activity in the field of the tasks description formalization. The following paragraph briefly presents several current studies going in this direction.

III.2 - CURRENT STUDIES CONTRIBUTING TO THE FORMALISATION OF THE TASKS DESCRIPTION: Regardless of exhaustivity, our aim is here to describe briefly four different approaches contributing to the formalization of the tasks description. It will be interesting to note the cutting out of formalism in several levels for each of these methods.

III.2.1 - THE A.B.S. SYSTEM: Montalban's work (1987) is placed in the frame of a design task. He has developed a processing architecture called A.B.S. (Architecture Based on Specifications), applied to the thermic design of lodgings. His formalism brings in a functional level and operational level: (i) the functional level is represented in a hierarchical way by an arborescence of functions of high level. Pre-conditions recapitulate the data which are necessary before the function launching. Post-conditions represent the data calculated by a function. (ii) The operational level is made of "models" or "prototypes" of tasks composed of a list of arranged production rules, a group of indicators, a task of exception which is called in case of blocking and its nature. A task is then considered as an instancy of this model completed by: an environment of execution and a task author.

The attribute task ensures here the link between the functional level and the operational level. Therefore, the task represents the action or the procedure to execute in answer to a functional need. The most important result, according to Montalban - he has implemented the A.B.S. system with the help of the generator of expert systems SMECI - is the considerable gain brought by the system in terms of flexibility of knowledge use. Moreover, taking into account the functional aspect of the objects ensures the expert system of a better quality of the Man-Machine dialogue, dialogue which is carried out in terms of functionalities. Finally, at the level of the knowledge acquisition, thanks to the A.B.S. system ability to extract a dynamic control structure from a static functional description, the expert system constructor doesn't think about the train of tasks.

III.2.2 - HELP TO THE TASKS OF SCIENTIFIC COMPUTATION: Pierret-Golbreich's works (1988) in the field of help to the tasks of scientific computation present a common principle in a task formalization. Indeed, the task is formalized under the form of an object describing in a declarative way its functional and operational levels: (i) The functional level refers to the execution conditions of the task (example: input/output type ...), as well as to its effects (parameters calculated by the task). (ii) The operational level refers to the action or to the tasks to be executed in answer to a given functional context.

Then, Pierret-Golbreich defines a task as a generic object described by its initial state, its final state and an operator. The operator refers to the operational level described by its inputs, its outputs, its use conditions and its "frame" (the "frame" is here a primitive action, a task of high level, or a list of sub-tasks).

III.2.3 - THE HIERARCHICAL PLANNING AS A METHOD OF THE TASK ANALYSIS: Sebilotte (1987) used the hierarchical planning paradigm in artificial intelligence (Sacerdoti, 1987) where each individual stage in a plan is considered as a task with its own inputs, conditions, goals, and so on. Therefore, in the frame of an office task analysis, Sebilotte considers that any given task may be decomposed according to models having four principal levels: (i) the most abstract level representing the general formulation of the task or the goal to be reached, (ii) the level "expert" which describes the procedures or the specific sub-tasks of a precise field, (iii) the highest common level of the general procedures level: - procedures which are independent on the field and used by the subjects in order to execute the specific procedures, and procedures which are very like more general knowledges; (iv) the lowest level or the elementary actions level, which belong to the field of automated activities.

The author underlines three advantages of this approach consisting in formalising a task under the form of a hierarchy of representation: (i) the model of the activities resulting from this, account for the way the expert subjects see the planning of their activity, (ii) the different levels of representation used authorize more flexibility. Indeed, depending on the situations he will be confronted with, the operator will be able to adapt his procedures by choosing the goals he wants to execute at the level of detail that he wants, and to choose the execution order of these goals and sub-goals.

A task model at different levels of details also helps proposing some guides or aids to the user as well as to the beginner, and to control the task progress.

III.2.4 - THE ANALYTIC METHOD OF TASKS DESCRIPTION (M.A.D.): The work of Scapin and Pierret-Golbreich (1989) takes place in the field of the help to the office tasks. In this aim, the leading concepts introduced in their formalism are those of object task, of action and of structure. The task concept is represented by a generic object called object task, and composed of an initial state, a final state, a goal, pre-conditions and post-conditions. Thus, the object task is the root of two subclasses: The "elementary task" class and the "composed task" class: (i) The elementary task is an irresolvable task, which operational level is characterized by an object method of simple type, that is to say an action. (ii) The composed task is a task which operational level is defined by a structure describing the task body. The structure object is represented by a generic object characterized by the constructor describing the arrangement of the various tasks involved and the constructor arguments. Then several constructors have been defined, such as: SEC: sequential task, PAR: parallel task, ALT: alternative task, ITER: repeated task and FAC: facultative task.

As a conclusion, Scapin and Pierret-Golbreich underline that the formalism will, only with use, demonstrate its possible utility, on the one hand during the evaluative study, on the other hand in the future works which will consist to define some ergonomic design tools, from the tasks description. They wish that this formalism will help underlining in a better way the difference between functional logic and logic of use in the interface design, taking into account the operator features and task, instead of essentially taking into account the functional logic of the application and of the constraints which are imposed by the computer.

III.2.5 - CONCLUSION ON THESE FORMALISATION APPROACHES: Such works give interesting plans in the field of the Man-Machine engineering, in so far as the present research work aims at basing the design process on the processing modelization of the tasks to perform. Therefore, this work puts in evidence the necessity to check off and to organize in several levels the data related to the tasks, the stage then permitting the creation of an ergonomic data base, which goal is to easy the Man-Machine interface design.

Our present works are going this way and consist in studying a global ergonomic methodology of graphical displays design integrating an ergonomic expert tool in the field of continuous industrial processes.

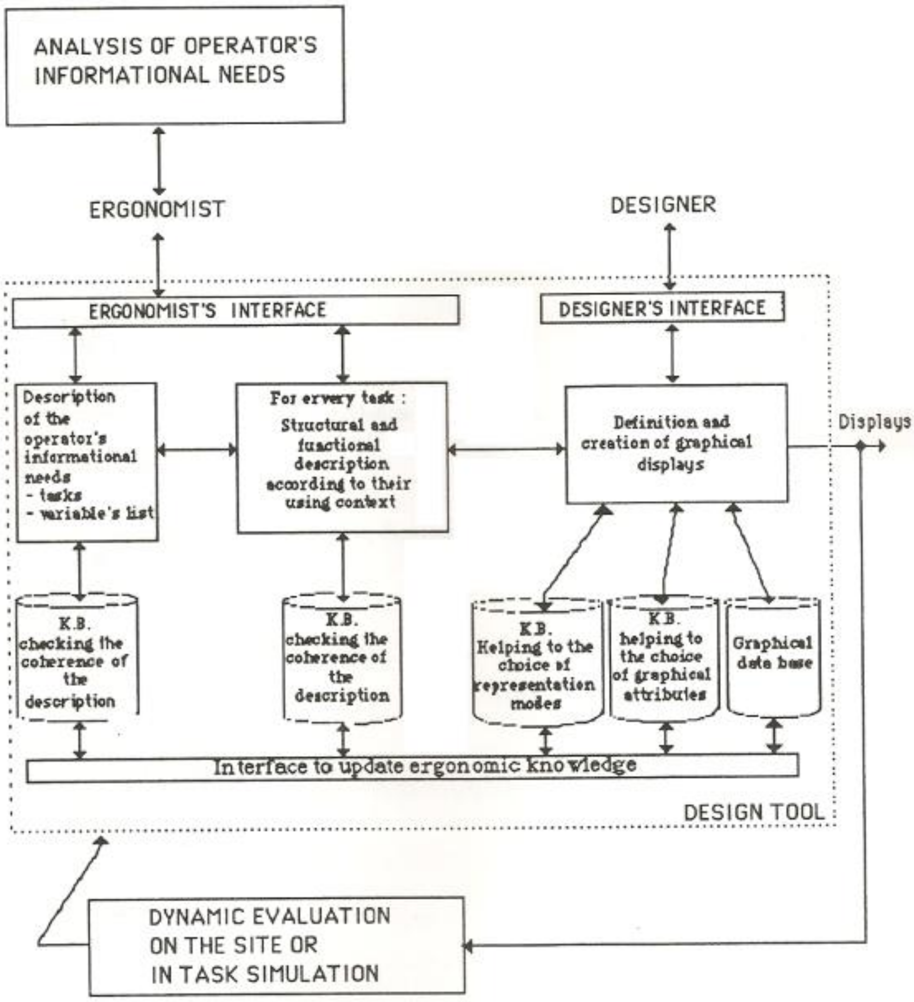

Figure 3: A model of an interactive expert system of ergonomic design integrated into a global design methodology

VI - STUDYING A GLOBAL ERGONOMIC METHODOLOGY OF GRAPHICAL DISPLAYS DESIGN INTEGRATING AN INTERACTIVE EXPERT TOOL

The aim of this formal tool, based on an oriented object expert system architecture, is to assist the graphical displays designer in order to avoid some ergonomic errors with regard to the operator real needs in the displays structuralization, the choice of some methods of graphical representation (curve, bar graph, ...) and of some chosen graphical attributes (color, characters size, ...). So as to do that, the system must integrate a description of the operational various contexts of the process and of the tasks to perform. Therefore, this system in essentially made of 3 modules, figure 3 (Moussa & al., 1990): (i) a module of classification of the operator's informational needs, (ii) a module which must define the display description at two complementary levels: a first level of the structural description of the display and a second level of the functional description, (iii) a module of graphical definition and creation of the display.

These modules are subsequently explained in the following part.

IV.1 - THE MODULE OF DESCRIPTION OF THE OPERATOR'S INFORMATIONAL NEEDS:

From a description of the operator's informational needs in the various operational contexts of the process, it is then easier to deduce the skeleton of the synopsis in creation. Therefore, the first interactive module must help strictly identifying, -before the graphical creation - the various contexts, the sets of variables, the system users, etc. A processing solution to the problem of knowledge representation can be a data formalization in a first representation under the form of structured objects in relation, by a semantic network supplying the other modules of the channel. Thus, regardless of exhaustivity in our description, it is possible to describe the objects "variable process", "task" and "system". For example, with the help of some attributes such as:

"VARIABLE PROCESS" OBJECT:

* name
* abbreviation
* symbol used
* type: boolean, analogic, discret
* domain of variation
* link with the different systems:
  - system name
  - role of the variable in the system
  - function in the system
* alarm's levels
* type of control: manual, automatic, regulation ...

"TASK" OBJECT:

* name
* task type: supervision, control, transition, diagnostic
* starting state
* state wished at the end of the task
* frequency
* concerned system
* the operator knowledge towards the system
* gravity level
* criterion to be respected
* associated sub-tasks
* event setting on the task
* event stopping the task
* list of variables:
  - set function
  - frequency of use in the task
  - level of importance in the task
* set used simultaneously
* data or document used with the set ...

"SYSTEM" OBJECT:

* name
* type: global, sub-system
* function
* inputs
* outputs
* list of the variables affected
* description of the normal functioning
* list of the possible difficulties (perturbation name, possible frequency)
* list of the data available on the system ...

As for the network, it can have the following structure, Figure 4:

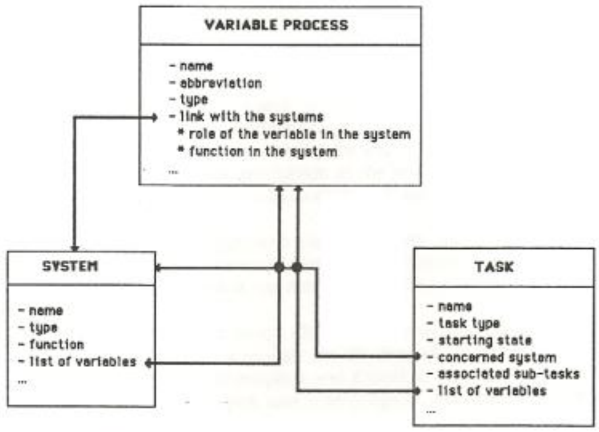

Figure 4: Simplified network of objects

The general coherence of the semantic network can be ensured, for one part, thanks to rules checking for example the total distribution of all occurences of an object class in the other object classes forming the network. For instance: Knowing that a task is created thanks to a whole of activities, we have the following rule:
"The union of the activities appearing in the group of tasks must be equal to the group of occurrences of the activities constituting the class of the object "activities".

IV.2 - THE MODULE FOR FUNCTIONAL AND STRUCTURAL DESCRIPTION: Each task is decomposed in a group of displays to create. This second interactive module must then help the ergonomist to ensure the description of each of the displays according to complementary levels:

- A first level of the structural description of the display: it aims at associating to every kind of display the adequate structure. The ergonomic recommendations proposed by the expert and centralized in knowledge bases help deciding on the right structure to use -
For example: *spare a zone on the left hand side of the screen for the alarms*.
- A second level of the functional description: it aims at defining the set of the tasks which the operator in charge of control and supervision will have to perform across the graphical display. Thus, we determine the functional aspects of the display associated to different tasks; we determine also the description of the procedures which will be implemented to meet the functional level.
For example: *the display must help the graphic representation of variables T2 and T4' trend*.

At the end of the step, the semantic aspect of each display is completely described and stored into a database -this display is used by the following third module which performs the graphical definition and creation of the display.

IV.3 - THE MODULE FOR GRAPHICAL DEFINITION AND CREATION OF THE DISPLAYS: The last module of the chain permits to the designer to define and create the display thanks to a graphical editor. A knowledge base involving ergonomic rules related to the ergonomic presentation of information aims at guiding the designer while he chooses the definition of the presentation information:

* Type1: A first knowledge base created to help the designer while he chooses the representation modes.
Example: IF *the operator has to visualize a variable tendency* THEN *propose a 'curve' type representation*.

* Type2: A second knowledge base assists the designer while he chooses graphical attributes.
Example: IF *the variable X is in a normal mode* THEN *use green color*.

* Type3: A third knowledge base proposes -from conclusions of rules type1- predifined modes of representation included in data base -from conclusions of rules type2- and prints them on

the screen.

Example: IF *mode of representation of type 'curve' is chosen for variable X* THEN *print in a window (for eventual selection by the designer) the predifined curve with the parameter 'color' selected for variable X.*

This stage of definition and graphical creation of the different displays leads to a version of the synopsis, ready for a "dynamic" evaluation on the site or in task simulation.

V - CONCLUSION

In this paper we have presented our current research works concerning the use of formalized ergonomic knowledge. The aim is the graphical Man-Machine interface design in the field of continuous complex processes. The first part has given a general idea of our work concerning the use of ergonomic knowledge by the expert system SYNOP, for the help to the static ergonomic evaluation of the graphical information presentation. This expert system currently under the form of a laboratory model, contains a hundred rules related to ergonomic general or specific concepts.

The second part of this paper dealt with an ergonomic design problem after examining the design notion in general. This part was illustrated by the brief presentation of several current research works of the tasks description formalization. These works contribute to the creation - at medium and long run - of formal tools for the Man-Machine graphical interface design.

Finally, the last part concerned the study of a design global ergonomic methodology, based on the use of an expert tool constituted of three major modules: a module for the description of the operator's informational needs, a module for the functional and structural description and a module for the graphical definition and the creation of the displays. The first model of this expert tool is in progress thanks to the expert tool SMECI on MICROVAX.

REFERENCES

BAILEY R. W., 1982. Human performance engineering: a guide for system designers. Prentice Hall, Englewood Cliffs, N.J.

BONNET A., 1984. L'intelligence artificielle : promesses et réalités. Interéditions, Paris, 1984.

BROWN D.C., CHANDRASEKARAN B., 1983. An Approach to Expert Systems for Mechanical Design. Conference on trends and applications. IEEE 25/05/1983 Gathersburg.

CAKIR A., HART D.J., STEWART T.F.M., 1980. Les terminaux à écran : agencement, ergonomie, organisation. Les Editions d'Organisation, Paris, 1980.

GOULD J.D., LEWIS C., 1985. Designing for usability: Key principles and what designers think. Communication of ACM, 28, 300-311.

DANIELLOU F., 1988. Ergonomie et démarche de conception dans les industries de processus continus, quelques étapes clés. Le Travail Humain, tome 51, n°2, 1988.

DE KEYSER V., 1988. Temporal decision making in complex environments.International Workshop on New Technology distributed decision making and responsability, Bad-Hombourg, May 1988.

ELZER P., BORCHERS H.W., WEIZANG C., ZINSER K., 1988. Knowledge-supported generation of control room pictures. IFAC Workshop Artificial Intelligence in real-time control, Clyne Castle, Swansea, Great Britain, September 1988.

FASSOTE D., 1986. Conception des Synoptiques sur C.R.T. destinés au Contrôle de Processus. In "L'homme et l'écran: aspects de l'ergonomie en informatique", Colloque de Nivelles "L'ergonomie en Informatique", Editions de l'Université de Bruxelles, Belgique, 1986.

GRZESIAK F., 1987. Représentation des connaissances et techniques d'inférence pour le maniement d'objets graphiques : application au système expert SYNOP. Thèse de Docteur-Ingénieur, Université de Valenciennes, Mars 1987.

HENDRICKS D., KILDUFF P., BROOKS P., MARSHAK R., DOYLEE B., 1982. Human engineering guidelines for managment information systems. U.S. Army Human Engineering Laboratory.

HOLLNAGEL E., WEIR G., 1988. Principles for Dialogue design in Man-machine systems. IFAC/ IFIP/ IEA/ IFORS conference, Oulu, Finland, June 14-16, 1988.

KOLSKI C., 1989. Contribution à l'ergonomie de conception des interfaces graphiques homme-machine dans les procédés industriels : application au système expert SYNOP. Thèse de DOCTORAT, Université de Valenciennes, Janvier 1989.

KOLSKI C., VAN DAELE A., MILLOT P., DE KEYSER V., 1988. Towards an intelligent editor of industrial control views, using rules for ergonomic design. IFAC Workshop Artificial Intelligence in real-time control, Clyne Castle, Swansea, Great Britain, September 1988.

KOLSKI C., TENDJAOUI M., MILLOT P., 1990. An "intelligent" interface approach. The second International Conference on "Human aspects of advanced manufacturing and hybrid automation", Honolulu, Hawaii, USA, August 12-16, 1990.

LAWSON B., 1980. How designers think. Architectural Press, London 1980.

LUCONGSANG R., NOUVELLON P., 1986. Démarche ergonomique intégrée à une méthode d'informatisation. L'Homme et l'Ecran : aspects de l'ergonomie en informatique, actes du congrés de Nivelles : l'ergonomie en informatique, Editions de l'université de Bruxelles, Belgique 86.

Mc CORMICK E.J., SANDERS M.S., 1985. Human factors in engineering and design, fifth edition. Mc Graw-Hill International Book Company, New York, 1985.

MILLOT P., WILLAEYS D., 1987. Les approches intelligence artificielle dans les systèmes de supervision. ENAC Intelligence artificielle et contrôle de la navigation aérienne, Toulouse, 1987.

MINSKY M., 1975. A framework for representing knowledge. The Psychology of Computer Vision, Editions P.H. Winston, Mc Graw Hill, New-York, p. 211-280, 1975.

MONTALBAN M., 1987. Prise en compte de spécifications en ingénierie, application aux systèmes expert de conception. Thèse de doctorat science en informatique. 17 novemvre 1987. Université de Nice.

MOUSSA F., KOLSKI C., 1989. Mise en oeuvre d'une base de connaissances ergonomiques exploitables par le système expert SYNOP pour l'aide à la conception d'images embarquées en automobile et évaluation. Rapport final de contrat RENAULT n° UV/14, LAIH, Université de Valenciennes et du Hainaut Cambrésis, Février 1989.

MOUSSA F., KOLSKI C., MILLOT P., 1990. Etude de l'intégration d'un outil expert interactif ergonomique dans la démarche globale de conception d'interface graphique homme-machine. Colloque International "l'Ordinateur, l'Homme et l'Organisation II", Nivelles, Belgique, 9-11 Mai 1990.

MURCH G.M., 1984. Physiological Principles for the Effective Use of Color. IEEE Computer Graphics & Applications, Vol. 4 n°11 pp. 49-59, 1984.

PIERRET-GOLBREICH C., 1988. Vers un système à base de connaissances centées objets pour la modélisation de systèmes dynamiques en biologie. Thèse de l'Université de Compiègne, Novembre 1988.

SACERDOTI E.D., 1977. A structure for plans and behavior. Elsevier, computer science libary.

SCAPIN D., 1986. Guide ergonomique de conception des interfaces homme-machine. Rapport technique INRIA, n°77, Le Chesnay, 1986.

SCAPIN D.L., REYNARD P., POLLIER A., 1988. La conception ergonomique d'interfaces: problèmes de méthode. Rapport de recherche n° 957, INRIA, Décembre 1988.

SCAPIN D., 1988. Vers des outils formels de description des tâches orientés conception d'interfaces. Rapport technique I.N.R.I.A. n° 893, Le Chesnay 1988.

SCAPIN D., PIERRET-GOLBREICH C., 1989. MAD : une Méthode Analytique de Description des Tâches. Acte du colloque sur l'ingénierie des interfaces Homme-Machine. Sophia-antipolis, 24-26 Mai 1989.

SEBILLOTTE S., 1987. La planification hiérarchique comme méthode d'analyse de la tâche : Analyse de tâches de bureau. Rapport technique I.N.R.I.A. n° 599, Le Chesnay 1987.

SHNEIDERMAN B., 1980. Software psychologie. Winthrop, Cambridge, MA.

SHNEIDERMAN B., 1987. Designing the user interface: strategies for effective human-computer interaction. Addison-Wesley.

TABORIN V., 1989. Cooperation entre Opérateur et Système d'Aide à la Décision pour la Conduite de Procédés Continus : Application à l'Interface Opérateur Système Expert du Projet ALLIANCE. Thèse de Doctorat, Université de Valenciennes et du Hainaut Cambrésis, Mars 1989.

TABORIN V., MILLOT P., 1989. Cooperation Between Man and Decision Aid System in Supervisory Loop of Continuous Processes, 8'th European Annual Conference on "Human Decision Making and Manual Control", June 1989, Lyngby, Danemark.

VALENTIN A., LUCONGSANG R., 1987. L'ergonomie des logiciels. ANACT, Collection Outils et Méthodes, Paris, 1987.

WOODS D.D., ROTH E.M., 1988. Aiding Human performance: From Cognitive Analysis to support systems. Le travail Humain, tome 51, n° 2, 1988.

WOODS D.D., WISE J.A., HANES L.F., 1981. An evaluation of nuclear power plant safety parameter display systems,. Human Factors Society, 25th Annual meeting, p. 110-114, 1981.