# A rule-based approach to the ergonomic "static" evaluation of man-machine graphic interface in industrial processes

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# A RULE-BASED APPROACH FOR THE ERGONOMIC "STATIC" EVALUATION OF MAN-MACHINE GRAPHIC INTERFACE IN INDUSTRIAL PROCESSES

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This paper aims at describing a rule-based approach for the ergonomic "static" evaluation of man-machine graphic interface in industrial processes. In the first part, we present some research works that directly or indirectly contribute to the ergonomical design or evaluation of man-machine interfaces. In the second part, we propose an ergonomic methodology for man-machine interface design. In a way to improve the information presentation, this methodology includes an expert system called SYNOP. This system is described in the third part of the paper. Finally, the last part discusses about the possible interest of such a rule-based approach.

## 1. INTRODUCTION

During the last decades, the swift evolution of industrial technologies, the complexity level of certain equipments, the development of automation and computer science in all fields have led to important changes in the content and methods of human work. The place of man in the system, his role, the required professionnal qualifications and his level of autonomy have since then been tremendously modified (Sperandio, 1988; Millot, 1988; Johannsen, 1990a).

In the field of automated industrial processes for instance, the new and essentially mental activities entrusted to the operators are representative of this evolution. Graphic interfaces are often used to synthesize the process state and help the operator in performing control and supervision tasks. These interfaces are constituted into graphic control displays and centralized on one or several screens. The manner of presenting and organizing the graphic information also plays a leading part in the efficiency and the reliability of human operator. So the interest given to the quality of the man-machine dialogue is growing.

Without exhaustive cares, it is possible to cite many different works that directly or indirectly contribute to the ergonomical design or evaluation of man-machine interfaces. Aiming at an ergonomical design, many research works are now being carried out, in order to define operator models in problem resolution tasks. Methods based on Artificial Intelligence start coming out, such as MESSAGE (Tessier, 1984) or KARL (Knauper & Rouse, 1985). More recently, the GRADIENT projet (a part of ESPRIT project) is devoted to the development of a set of cooperating expert systems for supporting control room operators as well as designers of graphical dialogue in the area of process supervision and control (Elzer, Borchers et al., 1988; Johannsen, 1990b). In parallel with these approaches, research works about the designing of human error tolerant interfaces are led, for instance Rouse & Morris (1985) : the method consists generally on watching human operator activities in order to identify, using a human predective model, actions that don't satisfy some criteria, such as security. These research works done on the designing of human error tolerant interfaces are based on human operator reliability, which is the object of many human error classification studies, such as Leplat (1985). At the ISPRA research center, work is being done to create a behavioural model of operator driving an automated process, using fuzzy sets (Bersini, Cacciabue et al., 1988; Cacciabue & Bersini, 1988). The model helps to study human operator's behaviour in particular driving situations. This modelling approach is at present being implemented on a cognitive module called BRAIN (Nordvik, Cacciabue et al., 1988), based on techniques issued from Distributed Resolving Problems. Please note that the techniques on distributed resolving of problems are more and more solicited for human operator's behaviour modelling. So, another aplication based on a blackboard architecture, OFMspert model (Rubin, Jones et al., 1988) can also be quoted, which tends to modelize the human operator's intentions in a blackboard. We can also cite Chaib-Draa (1990) which propose to formalize the mental states of an agent by using a logical formalism. A plan of his works concerns the cognitive modelization of a human operator in a control room, by using the notions of knowledge, intention and action.

In order to improve the perception and the interpretation of the information, we can quote much ergonomical research which has lead to study and evaluate new representation modes of graphical information. For example Beringer (1987) proposes new modes of graphical representation based on "the star display" (see 4.1), which the principle is defined by Coekin (1968); Brown (1985) compares many graphical methods in data processing tasks; Elzer, Siebert et al. (1988) study and assess some new representation modes in the process control field; Lind (1982) introduces functionnal formalism to a process behavior describing, nowadays used in many industrial applications; Siebert, Sicart et al. (1988) compare the operator's performance using three kind of interfaces, in a accidental situation setting on a nuclear reactor simulator. We can also cite the new programming techniques derived from Artificial Intelligence which help designing and creating original communication products. Indeed, new word processing techniques such as hypertext, or modern hypermedia technologies offering simultaneous word, graphics and sound processing do indeed increase their efficiency. The evolution of knowledge in the field of interactivity does also involve their ergonomical characteristics. So, many authors such as Kolski & Millot (1990) think that these communication techniques will thus definitely play an increasing part in the field of complex industrial processes.

Furthermore, it's necessary to notice here works leading to an ergonomical approach modelling of interface design. In this case, Norman (1986) suggests to begin with the user needs, which are still to be defined; many other authors as Gould & Lewis (1985), Scapin, Reynard et al. (1988), and Valentin & Lucongsang (1987) propose the users directly take part in the design process. In their studies, Scapin, Reynard et al. make ergonomical suggestion synthesis and identify 15 steps for ergonomical interface design. Visser (1988) presents a general architecture describing a design activity issued from the remarks of specialists.

As explained Coutaz (1988), it is sure that the design of interactive systems can be effected without ergonoms, but the programmer remains indispensable during the software developments. Thus, for taking into account the human factors during the design or evaluation of interactive systems, the methods used as yet consisted in using ergonomic guidelines like (Cakir, Hart et al., 1980) or (Mc Cormick & Sanders, 1985). Of course the guidelines proved their usefulness in improving working conditions through explaining the elementary ergonomic principles. Meanwhile a guideline can prove to be proving insufficient in so far as it does not immediately and naturally instil into the reader rigourous ergonomic methodologies of design and improvement of control displays. Another method consists in the intervention of an expert in the ergonomic field. This method seems at present under-employmented. Indeed a recent analysis of industrial projects in France (Maire & Brument, 1988) shows that the appeal to an expert in this field concerns only a low proportion of the analysed industrial projects. So when an expert is consulted, it is often at a late step of the detailed study, and principally about the physical appointments of the control room (furniture, lighting, etc). We must also underline that his intervention can become repetitive and long during an evaluation and improvement step of a graphic library constituted with several thousands of displays.

In the meantime, new computer solutions which allow to improve the ergonomy of the interfaces are at present appearing. So the achievement of interactive systems can lean on new computer techniques. A promising one seems to be a rule-based approach (Coutaz, 1988; Elzer & Johannsen, 1988; Millot, 1988; Kolski, 1989). This approach consists in ergonomically assisting the designer by means of an expert system integrating ergonomic knowledges in its bases. This type of tool particularly concerns our research. It is illustrated in this paper by a description of an expert system called SYNOP. In a way to improve the information perception, this expert system is used in a global ergonomic methodology for man-machine interface design. This methodology is now described.

## 2. ERGONOMIC METHODOLOGY FOR MAN-MACHINE GRAPHIC INTERFACE DESIGN

The proposed methodology is a synthesis of the studies of Fassotte 1986) and Millot & Willaeys (1987). It can be integrated in the more general methodology, of control room design, studied by Vittet (1981), Forster (1984) or Daniellou (1986; 1988). This methodology consists of seven major stages, fig.1 (Kolski, Tendjaoui et al., 1990; Taborin & Millot, 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. For instance, in a diagnosis task on a specific engine, the operator needs a particular piece of information which is useful only for a specific type of engine trouble. This information is then selected and associated to its context use (Taborin, 1989).

- 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 display displays the values of a temperature and two pressions.

- 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, colour coding, etc. For instance, a function which permits to display a curve is placed on the center of the screen, associated with a title, graduations and axis. Furthermore the colour of the curve display is green if the variable is in normal operation mode or red if the variable is in abnormal one.

-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 colours (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 termes 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). For instance, the expert system SYNOP has been designed for evaluating and improving industrial supervision displays. This system is described in this paper.

- The "dynamic" stage is carned 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 questionnaries, 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, fig. 1.

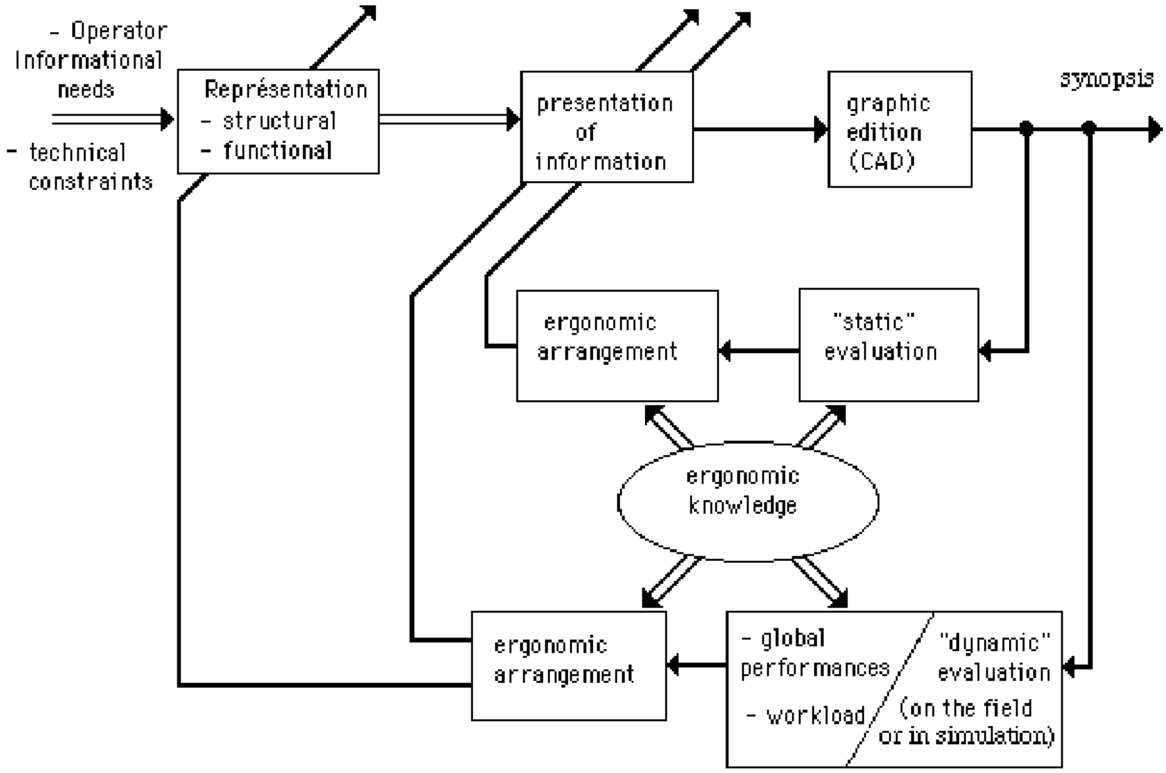


FIG. 1. Ergonomic methodology for man-machine interface design

The interest of the methodology consists in taking into account the human factors in the design loop of the displays. These factors are particularly treated in the "static" and "dynamic" ergonomic stages. But it is necessary to add that the actual tendancy of the designers which lead to recommend the screens for unique information support must be considered with care. Indeed in the information system used by the operator, a particular place must be reserved for the verbal communications and their functional utility (Van Daele, 1988).

This paper concerns especially the "static" evaluation of Man-Machine graphic interface. So the next part describes our ergonomic knowledge-based approach : the expert system SYNOP.

## 3. THE EXPERT SYSTEM SYNOP

SYNOP is an expert system for static ergonomic evaluation of graphic industrial control displays. This system is able to make automatic improvements on displays and to provide the designer with ergonomic advice, by production rules contralized in knowledge bases (Kolski, Binot et al., 1988; Kolski, 1989). The general structure of the system is described in the following part.

### 3.1 THE STRUCTURE OF THE EXPERT SYSTEM SYNOP

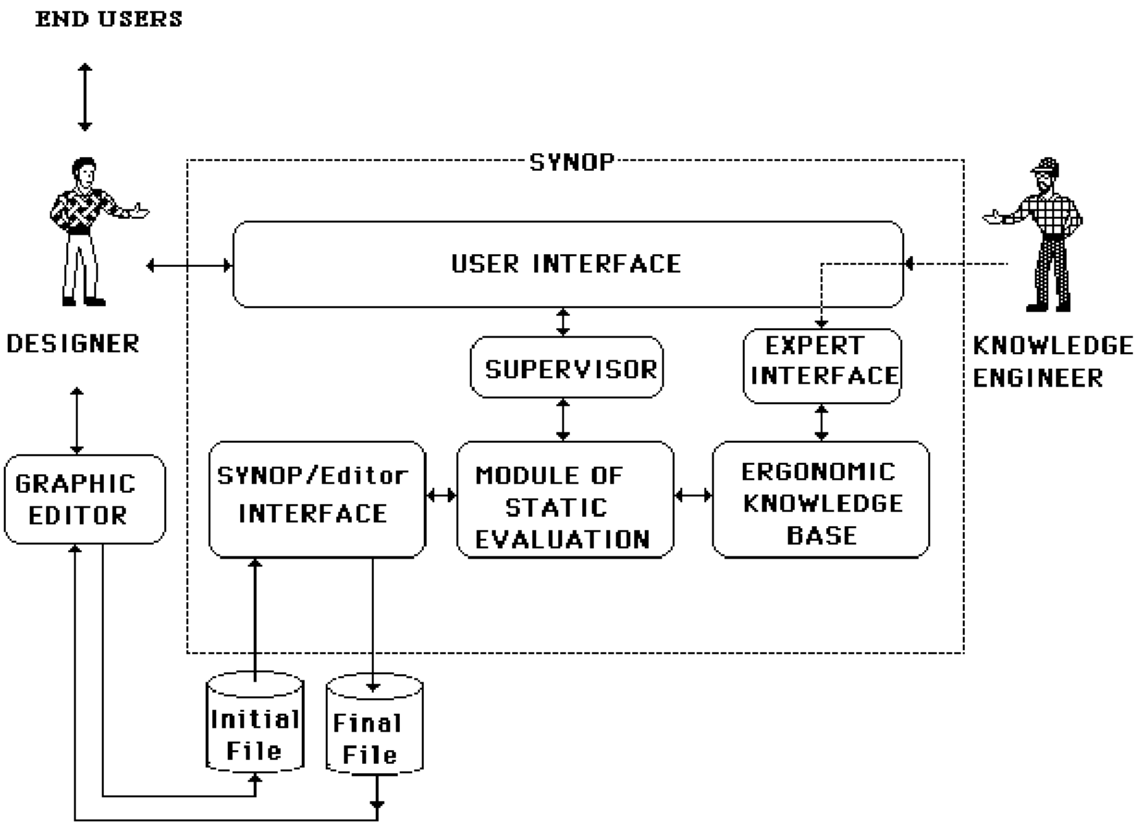


FIG. 2. The structure of the expert system SYNOP.

Developed in LISP, the system uses a first order inference engine (Grzesiak, 1987) and the notions of frame (Minsky, 1975) and semantic network (Bonnet, 1984) for knowledge representation. For the time being, it is interfaced with a graphic editor using a G.K.S. package for creating displays. The structure of the expert system is described on figure 2.

SYNOP includes a module for the static evaluation of graphic control displays. The role of this module is to evaluate and improve the displays which have been initially created by the designer with a graphic editor, and automatically stocked into initial files. An interface between SYNOP and the graphic editor interprets these files to create a semantic network of structured objects describing the display. The ergonomic rules contained in the knowledge base are able to modify the attributes of the objects, for instance the height of a character or the colour of a curve, according to ergonomic rules of presentation on a graphic screen.

The improved semantic network is then reconstructed by the interface between SYNOP and the graphic editor into final files. These files correspond to an ergonomic display which can be displayed on the screen by the designer. SYNOP has two man-machine interfaces managed by a supervisor : the user interface is used by the designer to start and control the module of evaluation; the expert interface is used by the knowledge engineer to introduce and update the ergonomic rules of the knowledge base. This knowledge base is shared in "knowledge sub-bases" each related to an ergonomic theme, and into "meta-knowledge sub-bases" which contain selection criteria for the "knowledge sub-bases".

The module of static ergonomic evaluation is now presented.

## 3.2 THE MODULE OF STATIC ERGONOMIC EVALUATION

The principle of static ergonomic evaluation can be described by three phases. The first phase consists in interpreting the graphic files related to the treated display in order to create a semantic network of LISP structured objects. The second phase concerns the ergonomic evaluation of the network's objects. For this purpose, the rules contained in the selected "sub-bases" are activated in view to improving the presentation of the graphic display. Finally, the third phase permits to reconstitute the graphic files corresponding with the improved display in order to display them on the screen. These three phases are described in more detail below.

### 3.2.1 INITIAL PHASE OF INTERPRETATION OF THE GRAPHIC FILES INTO A SEMANTIC NETWORK

The first phase consists in interpreting the static and dynamic graphic functions in view to creating a semantic network of LISP structured objects describing the display. This information is created and automatically centralized by the graphic editor into binary-coded files. These files are decoded by the displays interpretor integrated into the interface between SYNOP and the graphic editor, figure 3. The principle of this interpretor consists first in reading the graphic files and in transfering their content in the LISP work environment. Then, structured objects are progressively created by the instanciation of predefined LISP object prototypes for each possible type of graphic object.

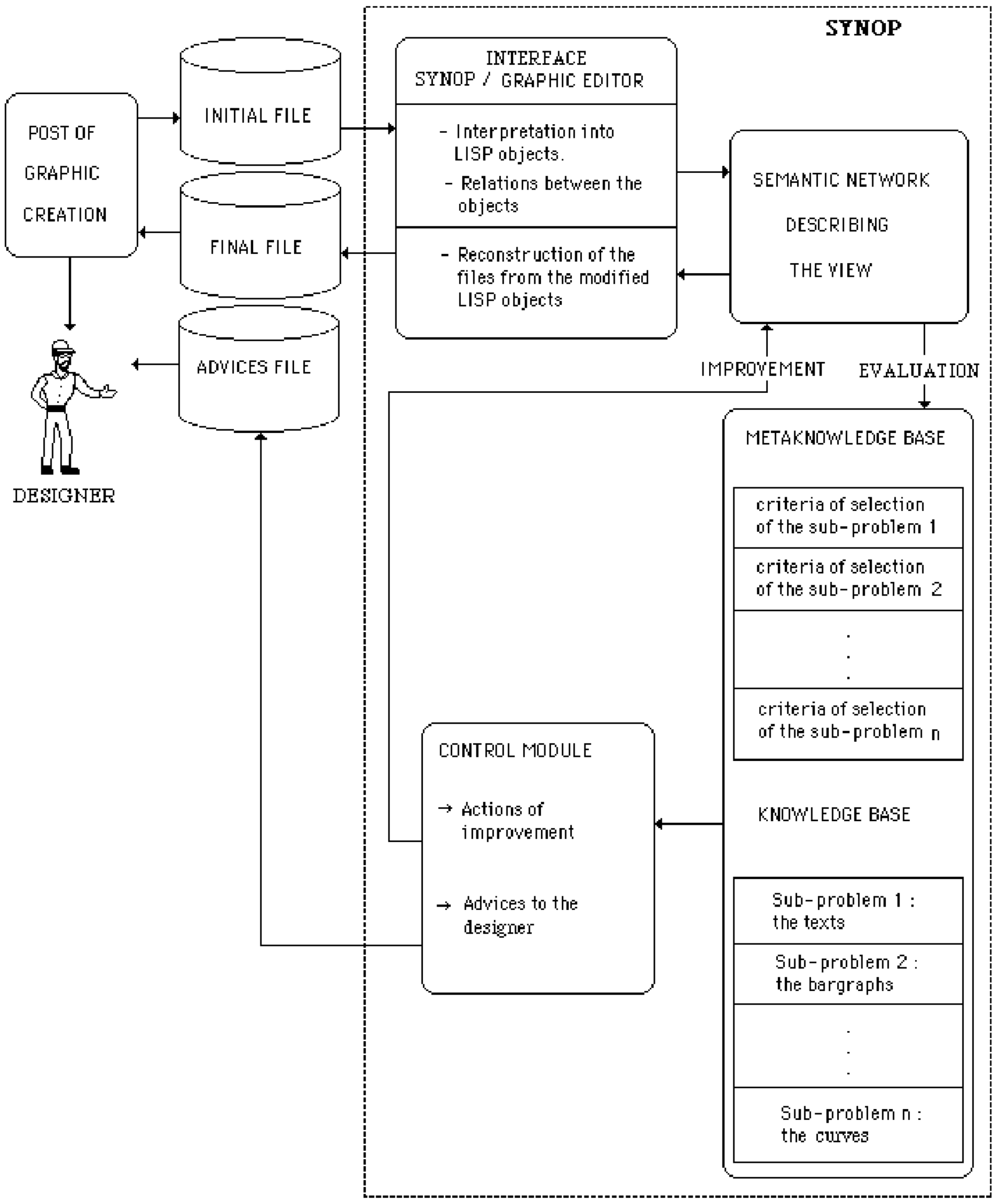


FIG. 3. The structure of the module of static ergonomic evaluation

The structure of these structured objects is inspired from the notion of frame (Minsky, 1975) and comprises the name, for instance "text7", see figure 4, and a set of attributes which caracterize them, like the "color" or the "height of character". Each attribute is described by the "value" slot, itself associated with a value, for instance "red". We can notice that there exists in the field of Artificial Intelligence a lot of other types of slots. But the "value" slot is sufficient here to describe a graphic object completely. The figure 5 presents an example of creation of the animated variable "bargraph2", by instanciation of the "bargraph" structure.

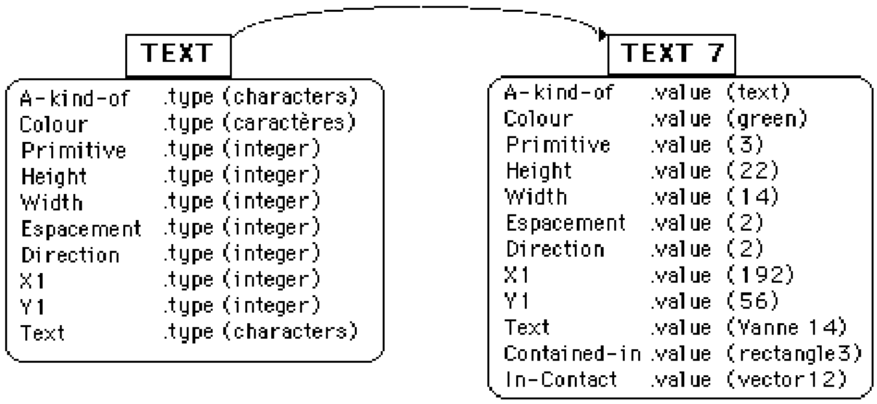


FIG. 4. Example of instanciation of a graphic primitive
(a) : object prototype
(b) : instanciation of the object prototype

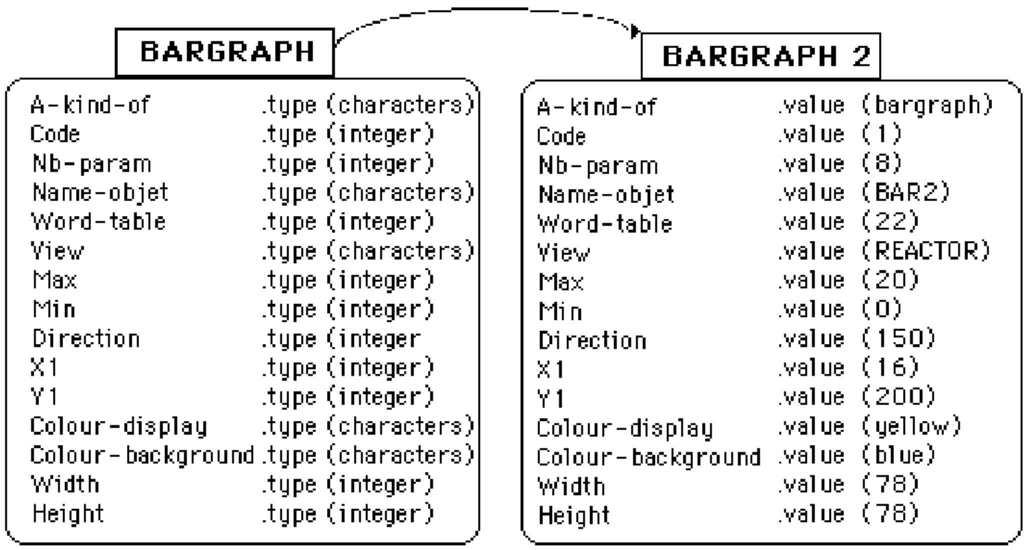


FIG. 5. Example of instanciation of an animated variable
(a) : object prototype
(b) : instanciation of the object prototype

Lastly, after this creation phase, the links between the objects are analysed and calculated with the view to allocating a value to the attributes of structural relations. For instance the attributes "contained-in" and "in-contact-with" describe the links between "text7" and : "rectangle3" and "vector12". After this phase, the objects constitute a semantic network, ready for the second phase of evaluation and improvement.

### 3.2.2 PHASE OF EVALUATION AND IMPROVEMENT OF THE DISPLAY

The ergonomic evaluation is carried out by inference of the rules contained in the knowledge base of SYNOP. The ergonomic knowledge is represented by production rules operating by a first order inference engine (Grzesiak, 1987). The engine is based on the sequence : definition of the set of applicable rules, choice of a rule, inference of the rule and up-dating.

The production rules formalism is of the the following type :

IF (P1 * P2 * ---* Pr) THEN C

The condition of application of a rule is a logic arrangement of premisses Pi. The operator "*" can take the value "AND" or "OR". With each premiss is associated a procedure, written in LISP, which allows to evaluate the verity value by a direct test on the graphic attributes of the objects describing the display. In the same way, the conclusion C is associated with a procedure which is able to automatically improve graphic attributes.

The evaluation of a display begins by a global evaluation of the objects with a view to selection of knowledge "sub-bases" contained in the knowledge base of SYNOP. Each of the "sub-bases" is related with the study of an ergonomic concept or theme, and contains a set of rules related with an ergonomic sub-problem. For instance a "sub-base" concerns ergonomic presentation of bargraphs and regroups a set of rules related to this sub-problem. Another "sub-base" can concern the lisibility of characters, coloured contrasts, and others.

The selection of "sub-rules" is effected by the activation of selection criteria, in the form of metarules contained in metaknowledge "sub-bases", figure 3. This method allows to restrict the work space, by limiting the step of applicable rules selection to a set of effectively applicable rules, and then to reducing the time of treatment, by avoiding testing useless rules.

An example of metarule is given below. In this example, x1 is a variable taking the name of the treated display for value. So, if there exists at least one bargraph in the display x1, the selection of bases related to this sub-problem is proposed to the operator.

| | | |
|---|---|---|
| IF | (there-exists-at-least-one-bargraph-in | x1) |
| THEN | (select-the-bases-over-bargraphs | x1) |

Then the display is evaluated by inference of action rules contained in each selected "sub-base". Two simple examples are presented below. The first rule allows the separation of two parallel texts, x1 and x2, from a distance equal to hundred per cent of the height of their characters, if this distance is initially lower to this reference value. The second rule allows to change the color of an object x1 if its color is red and if it's not in relation with the alarm notion.

| | | |
|---|---|---|
| IF | (parallel-texts | x1 x2) |
| AND IF | (distance-between-then<100%-height | x1 x2) |
| THEN | (set-distance- = 100 % height | x1 x2) |

| | | |
|---|---|---|
| IF | (color-red | x1) |
| AND IF | (don't-represent-an-alarm | x1) |
| THEN | (change-color) | x1) |

Meanwhile, in certain cases, such a modification of graphic attributes can be difficult or impossible. In these case, the expert system is content with providing the operator with general ergonomic advice concerning the treated display. Such rules can prove imprecise since they use subjective criteria of evaluation. Two examples of such rules illustrate these criteria. The first rule recommends the operator to not overload the display x1 with coloured zones when the total surface of these zones is greater than a predefined subjective value. The second rule indicates that an alphanumeric chain which includes more than 10 numeric and alphabetic characters can be difficult to interpret. In this second example the number 10 has been chosen but 8, 9 ou 12 would also be correct according to the context use of the display.

```
IF      (coloured-zones-surface-great        x1)
THEN    (reduce-this-coloured-surface        x1)

IF      (more-than-10-variables-in-the-display   x1)
THEN    (advise-less-than-10-variables           x1)
```

After this second phase of evaluation and improvement, the modified semantic network is coded in binary files which can be exploited by the graphic editor.

### 3.2.3 PHASE OF RECONSTRUCTION OF THE GRAPHIC FILES RELATED TO THE IMPROVED DISPLAY

The third phase concerns the automatical reconstruction of the binary files issued from the expert treatment, according to the inverse principle of those described in 3.2.1. These files are directly usable by the designer. The expert system provides the designer with more advice and explanation files which permit him to alter his display from these results of the expert treatment, and also to understand the reasoning of SYNOP. Indeed, these files have been progressively created during the precedent phase and provide the operator with a written trace of the ergonomic process.

After this third phase the treatment is finished. The designer can then leave the software environment of SYNOP in order to improve his displays with the given advices. He can also ask for another evaluation.

The expert system SYNOP is presently being validated in the lab. The methodology is tested on control displays corresponding with real or simulated applications. The possible interests of such a knowledge-based approach are described now.

## 4. THE POSSIBLE INTERESTS OF A SUCH KNOWLEDGE-BASED APPROACH

After the presentation of the expert system, it is now necessary to study the interests of a such tool, and the consequences with regard to the ergonomy of graphic information presentation. With this goal four classes of applications are considered in particular.

### 4.1 "STATIC" EVALUATION OF MAN-MACHINE GRAPHIC INTERFACE

In the first class, the goal of the system is to ergonomically assist the designer during the "static" evaluation step. Here SYNOP can help him to optimize the meaning of presenting the graphic information, without the human direct help of an ergonom. So SYNOP has been validated during the "static" evaluation of the graphic interface between the operators and a real time expert system. This application has taken place in the French project ALLIANCE aiming at implementing a real time expert system for alarm filtering, diagnosis, and trouble shooting (Taborin & Millot, 1986, 1988, 1989).

The process is a power station used for testing steam generators before they are implemented on real nuclear power plants. Its structure is similar to that of a nuclear plant : a heat generator produces and transmits energy to the steam generator which transforms it into pressurized water. The heat generator is made of electrical resistors. The process is controlled by a computer and supervised by human operators in a control room. The ALLIANCE project was supported by the French Ministry of Research and Technology. It was managed by CEA and regrouped several laboratories (LAG at Grenoble, LAIH at Valenciennes) and industrial compagnies of Artificial Intelligence (ITMI, IIRIAM), of engineering (SGN) and of production (EDF, SHELL). The expert system that has been developed currently predicts in a continuous way the future evolution of the process along a prediction horizon of several minutes (up to 15 min) with a prediction period of one minute (Caloud, 1988). It compares the future evolution of the process with alarm thresholds, and if need be, provides the operator with preventive advice. Our research work concerned the development of the interface between operators and the expert system. The interface has been designed according to the operator's informational needs in the different operation modes of the process : 1) monitoring of the normal operation and fault detection, 2) problem solving and trouble shooting in the abnormal operation mode.

One of the evaluated and improved views is presented and commented below. It consists of a synthetic view, called "star view", displaying the seven most significant variables of the process. The view has been developed according to the principle defined by Coekin (1969) and implemented later by Woods (1981). The initial "star view", figure 4-(a) was structured into four zones :

- a "work" zone which presents the "star",
- an "advices" zone which proposes prevention advices (on the right part and at the bottom of the screen),
- a "menu" zone which provides the operator with the usable displays (on the right part and at the top),
- a "command" zone which allows the call of a menu (on the left and at the top).

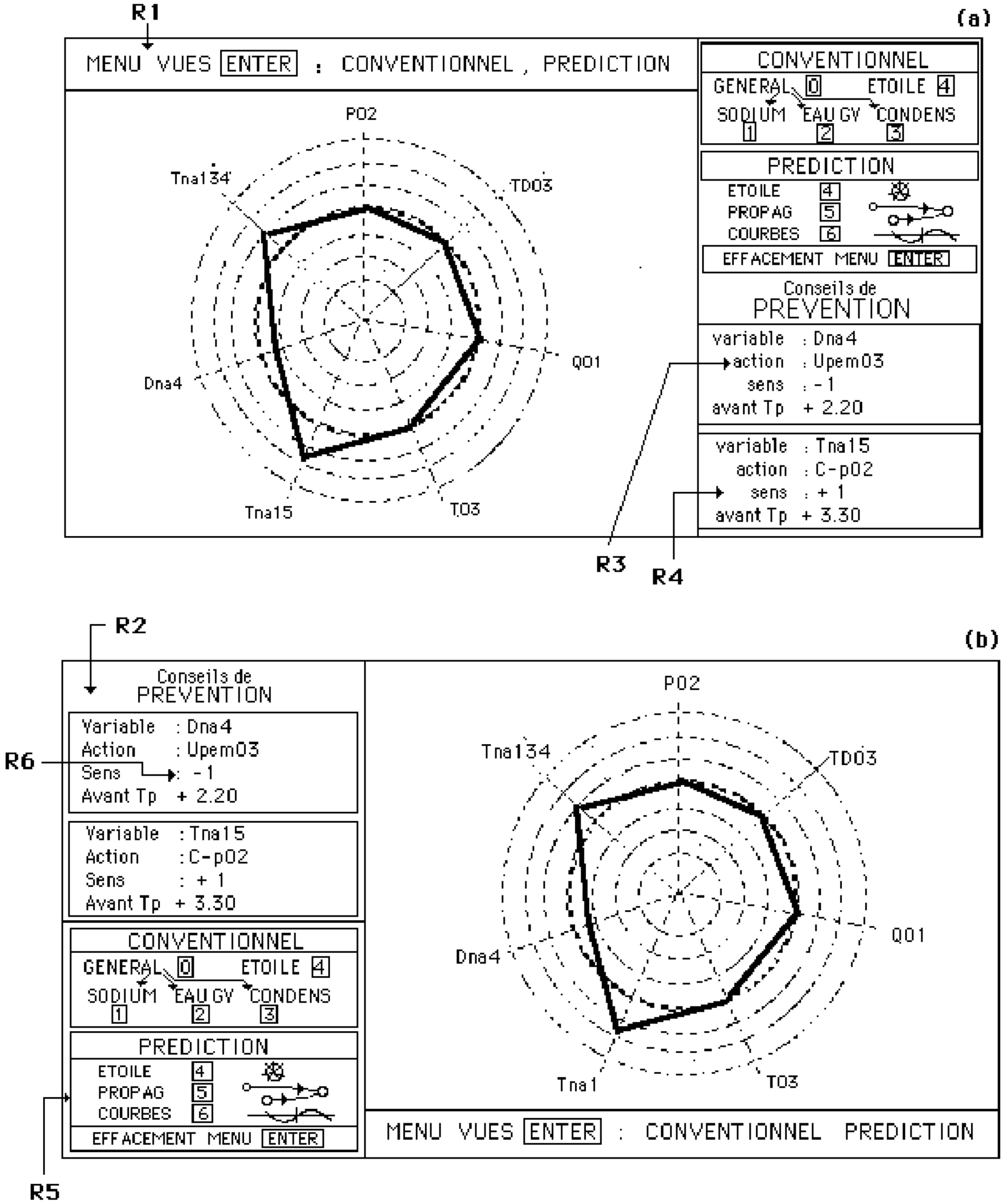


FIG. 4. A "star" display

(a) : before SYNOP processing

(b) after SYNOP processing

The knowledge implemented in the SYNOP bases is divided into two parts, the general knowledge and the specific knowledge (Kolski, Van Daele et al., 1988) :

- the general knowledge consists of ergonomic concepts usable for most of graphic applications : these rules constitute the basis of an ergonomic resentation of information on a graphic screen. For instance : rules related to character size, number of animated functions, use of color, information density, contrasts ...

- the specific knowledge consists of information presentation related to particular application. For instance : use of yellow color for predictions provided by the alarm filtering expert system.

The figure 4 presents a "star" display, before and after its treatment by SYNOP (For technical reasons, a hard copy of the real displays was not possible. So the displays have been drawn using the graphical editor Superpaint on Macintosh, and they can´t of course reflect exactly the reality). Remarks concerning the main ergonomic rules used by SYNOP for this display are now given. :

**R1** : the command for calling a menu, which is not an essential information, was placed on the left and at the top of the screen, that is in the zone the most frequently scanned by an operator (Sperandio, Bouju, 1983; Daniellou, 1986). Therefore it is more advisable to place it on the right hand part and in the bottom of the screen.

**R2** : the prevention advices represent very important information. They were placed on the right part, at the bottom of the screen. It is more advisable to place it on the left part and at the top of the screen (Sperandio, Bouju, 1983; Daniellou, 1986).

**R3** : it is more advisable to lay out the texts on the left (CFPJ-DGT, 1983).

**R4** : it is more advisable to begin the four texts by a capital letter (Grandjean, 1987).

**R5** : the information blocks must be distinguished from the lines constituting the information zone limits, in order to facilitate the blocks interpretation by the human observer.

**R6** : the two points constituting the character ":" were too near. SYNOP has leaved a space between them, in order to facilitate the character interpretation.

Complementary general remarks can be given :

- Yellow colour was used for displaying real time variable values, and green colour was used for presentation of predected values of the variables. Prediction role is to warn the operator pf possible process defects. In this case, yellow colour is then more advisable (Sallio, 1983). The colours of all the variables have been changed through this criteria.

- A lot of rules about use of characters have been infered. They concern for instance ergonomic heights, widths and spaces between characters (Mc Cormick, Sanders ,1985; Cakir, Hart et al. ,1980)

Many ergonomic improvements have been automatically made during the treatment of the expert system. So the designer has been discharged of correction tasks, which are often dull and long. After this static evaluation, the interface has been implemented in the power station at Cadarache and is being dynamically tested and evaluated with the operators.

## 4.2 SAVING AND STRUCTURATION OF ERGONOMIC KNOWLEDGE

The second class is relative to the saving and the structuration of the ergonomic knowledge of experts in ergonomics through an "expert" interface whose role is to create new ergonomic rules in the knowledge bases of the expert system. This knowledge can be general, like the use of colours or the density of information. They also can be specific to certain applications like process control, consultation of data bases or aeronautics. Such a step will permit an exhaustive list of actual existent ergonomic knowledge with a view to developing other expert system tools for interface design. It is important to notice here that the ideal during this knowledge acquisition would be to dispense with the knowledge engineer while permiting the expert to manage himself his knowledge in the bases of the system. This possibility would avoid the skew involved by the difference between the real expert knowledges and their interpretation and implementation in the bases by the knowledge engineer (Hayes-Roth et al., 1983). Such an approach is at present being studied in the lab.

## 4.3 COMPUTER-AIDED TRAINING IN THE FIELD OF GRAPHIC INFORMATION PRESENTATION

The third class concerns the use of SYNOP or of such an expert tool for Computer Aided Training in the field of graphic information presentation. Indeed such a tool can evaluate and improve graphic displays created by forming ergonoms or ergonoms which want to up-date their knowledge. This class naturally follows on from the precedent one. Such applications must be seriously considered because it is now necessary to take the growing importance of ergonomy in the field of interactive applications into account (Kolski & Millot, 1989).

## 4.4 ERGONOMIC DESIGN OF MAN-MACHINE GRAPHIC INTERFACE

The objective of the last class is to develop "intelligent" editors of industrial control displays, using rules for ergonomic design. For that purpose, we are at present studying the structure of a ergonomic knowledge-based tool which allow to help the designer in the choice of the representation modes (curve, "star" display, and so on) and of the graphic attributes, such as colour or symbol size (Kolski, 1989; Moussa & Kolski, 1989). the structure of this expert tool is composed by the chaining of three modules, each performing an accurate task in the ergonomic design of graphical interfaces. In fact, in every module, several techniques of representation and exploration of knowledge are used, such as production rules, semantic networks and frames (Moussa, Kolski et al., 1990b) :

- The first module of classification of the operators informational needs counted during the task analysis helps identifying -before the graphical display realization- the different contexts, the set of variables, the system users, and so on. The solution considered to face knowledge representation used in this module is the technique of the frames and the semantic network. The result of the first module are used by the rest of the expert tool.

- The second module must define the display description at two 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 recommandations proposed by the experts 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 functionnal description : it aims at defining the set of the tasks wich operator in charge of control and supervisory will have to perform accross the graphical display. Thus we determine the functionnal aspects of the display associated to different tasks, we determine also the description of the possible procedures that will be implemented to meet the functionnal level.
FOR EXAMPLE : The display must helps the visualizing variables tendency V1, V3.

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

- The third module of the graphical definition and creation of the display, using knowledge bases involving ergonomic rules relative to the ergonomic presentation of information aims at guiding the designer while he chooses the presentation information.

Three types of ergonomic knowledge are presently studied (Moussa, Kolski et al., 1990a) :

* Type 1 : A first knowledge base created to help the operator while he chooses the representation modes.
EXAMPLE : IF *the operator has to visualize a variable tendency*
THEN *propose a 'curve' type representation.*

* Type 2 : A second knowledge base assists the operator while he chooses graphical attributes.
EXAMPLE : IF *the variable X is in a normal mode*
THEN *use green colour*.

* Type 3 : 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 'colour' selected for variable X.*

A such theorical approach of ergonomic knowledge-based design is being studied in the lab. Our first research results will be presented in a next paper.

## 5. CONCLUSION

In this paper, we have presented a rule-based approach for the ergonomic "static" evaluation and improvement of man-machine graphic interface.

This approach is based on an expert system called SYNOP (for SYNOPsys) which contains ergonomic knowledge formalized into production rules. At present, the system contains approximatively hundred rules. These rules have been validated by experts in the field of Man-Machine Communication.

The first results show that this rule-based approach is promising. So we can envisage now several rule-based ergonomic applications such as "static" evaluation of man-machine graphic interface, saving and structuration of ergonomic knowledge, computer-aided training in the field of ergonomic knowledge, and ergonomic design of man-machine graphic interface.

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