A process method for the design of “Intelligent” man-machine interfaces: Case study: “The decisional module of imagery”

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A PROCESS METHOD FOR THE DESIGN OF "INTELLIGENT" MAN-MACHINE INTERFACES:

Case study: "The Decisional Module of Imagery"

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Abstract.

A new concept is appearing in the field of Man-Machine interaction: the design of "intelligent" interfaces. The aims of this paper are threefold, first to show what an "intelligent" interface is and present a five step design process for such an interface - specifically: (i) Man-Machine system analysis, (ii) operator, task and process modelling, (iii) specifying those assistance tools that form an "intelligent" interface, (iv) realization of the assistance tool, and (v) evaluation. The second part describes the structure of an "intelligent" interface, called D.M.I. (Decisional Module of Imagery), that is currently being developed, and the final part explains the D.M.I.'s development, using the five process steps outlined above.

I. INTRODUCTION

The increasing complexity of industrial processes necessitate the design of control, supervision and decision support tools that are able to evolve along with the control system. Such man-machine interfaces play a vital role where the information being manipulated becomes more and more complex i.e. safety systems, production control systems and environment protection systems. Current literature on the subject of man-machine interfaces provides the designer with support in a number of ways:

- Ergonomic guidelines such as those of Scapin (86), Shneiderman (87) or Gilmore et al. (89),

- Interface guidelines associated with specific machines such as the Macintosh. These guides give some recommendations aimed at ensuring consistent representation between interface components for different applications,

- General books in the field of Man-Machine interaction such as those of Helander (88), Coutaz (90), Falzon (90) or Weir & Alty (91),

- Interface design and evaluation models that can (i) be adjusted on the task as, for example, KLM & GOMS (Card et al., 83) models, (ii) grammatically describe the interface such as ALG (Action Language Grammar) presented by Reisner (82) or CLG (Command Language Grammar) presented by Moran (81), or (iii) be adjusted to an agent (or object), as MVC (Model, View, Controller) in Smalltalk (Goldberg, 84) or PAC (Presentation, Abstraction, Control) described by Coutaz (90),

- Literature dealing with Human Work Analysis and Evaluation. Such work paved the way for the attempts at improving Man-Machine interaction (see Wilson & Corlett, 90),

- or finally, pandemic methods of interface design, from man-machine system analysis to the evaluation of implemented interfaces: see for example Kolski et al. (90), Millot (90) or Tendjaoui et al. (to be published).

Some of these works display a new trend in the field of Man-Machine interaction that of the "intelligent" interface concept (Zachary, 86; Rouse et al., 87; Hancock & Chignell, 89). This concept is displayed in many different forms, for example: the adaptable or adaptive interface (Edmonds, 81; Rouse, 88; Hefley, 90; Browne et al., 90), the expert interface (Brajnik et al., 90) or the human error tolerant interface (Rouse & Morris, 85). In most cases these approaches use Artificial intelligence techniques to improve the interaction between man and machine and indicate in general the concepts of Assistant Operator and Intelligent Assistant System (Boy, 88; 90) or Intelligent Agent (Mandiau et al., 91a; 91b).

Primarily, our work concerns us with the study of the "intelligent" interface, and is aimed at realizing such an interface supervised by an "intelligent" manager called the D.M.I. (Decisional Module of Imagery). This paper is divided into three principal sections:

- The first section defines the "intelligent" interface concept with respect to the complex process control domain and is followed by a description of an "intelligent" interface design process.
- The second section presents a general framework for the "intelligent" image manager.
- Finally, the last section is devoted to the application of the "intelligent" interface design process in an experimental environment.

II. "INTELLIGENT" INTERFACE DESIGN METHODOLOGY - CONCEPTS AND TECHNIQUES

Our research works are orientated towards complex industrial processes and in this domain, our definition of an "intelligent" interface is: " a self-governing device, able to adapt itself to the operators informational needs". Consequently, it uses expert knowledge on (i) the different operating contexts of the process to be supervised and/or controlled, (ii) the characteristics of the operators using the interface according to the kind of task that they have to perform, and using the general model of problem solving (Rasmussen, 80; 83).

Our approach consists of using an expert system to improve the interaction between the process, the assistance tool and the operator (Tendjaoui et al., 90). As for all "intelligent" systems, such an interface design must be based on previous assistance tools and techniques whereupon Chignell & Hancock (88) stress three major criteria: task analysis, the use of expert systems and interface design tools.

We are in agreement with these authors, and describe in this section an "intelligent" interface design process. It is composed principally of five connected phases: (i) Man-Machine system analysis, (ii) operator, task and process modelling, (iii) the specification of the assistance tool incorporating the "intelligent" interface, (iv) implementing the assistance tool, and (v) evaluating the assistance tool. For each one of these five phases, we underline many obvious sub-problems. Table 1 shows our objects and examples of the techniques and tools used.

The science of "intelligent" interface design has only recently become one that is fully controlled, however, we aim at providing some points of reference in this field. Our design process is summarized below (see also figure 1 and table 1):

- The first phase begins with an analysis of the process, and outlines both normal and abnormal function modes allowing the definition of operator prescribed tasks. These tasks must consider all the operators resources and limits and outline all his assistance requirements. Thus, to perform his task, the operator may need specific tools for example: diagnosis support system, failure prediction support system, situation evaluation support system, and so on.

- In the second phase, we use artificial intelligence techniques to build three models: (i) an operator model, inspired from the general problem solving model of Rasmussen (80; 83), (ii) an assisted task model, using prescribed task definition (we must consider here the assistance brought by the assistance tools that were specified in the first phase) and, (iii) a process model. Techniques from the field of qualitative physics (Kuipers, 85; Caloud, 88; Ferray-Beaumont, 88) may be of particular interest during this phase for building the process model.

- The third phase aims at specifying both the "intelligent" interface and its software environment. Operator and assisted task model analysis lead to an "intelligent" graphics display specification (this point will be detailed below). For each display, we must define all the presentation modes and graphical attributes whilst still respecting the ergonomics of the presentation and is why we are working on the design and evaluation of graphic displays, using Artificial Intelligence techniques (see Moussa et al., 90; Kolski, 89; 91 or Kolski & Millot, to be published).

- The fourth phase is the implementation of the "intelligent"display manager using the operator model, assisted task model and process model. This display manager will be connected both to an ergonomically arranged graphics library and the" specific treatment manager". It will have to take on a decision support system role in order to optimize data emanating from the assistance tool. This phase gives us a complete assistance system that incorporates the "intelligent" interface.

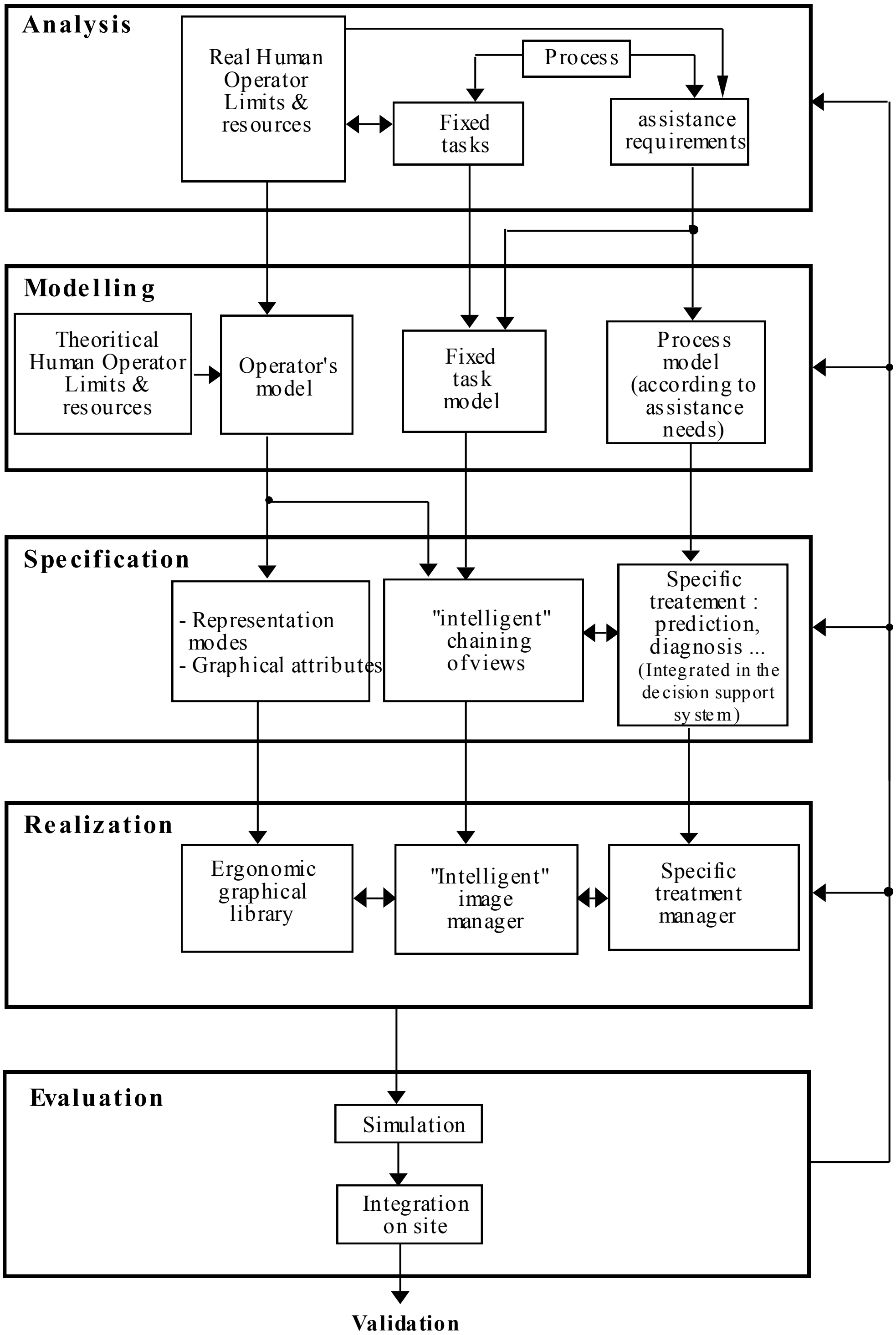

Fig. 1. "Intelligent" interface design process

- The fifth and final phase concerns the evaluation of the assistance system that has been realized. Evaluation will be considered firstly in a simulated process environment and secondly in an actual industrial setting. Literature on the subject of ergonomics is profuse especially in connection with the evaluation of interfaces, see for example the works of Wilson & Corlett (90), Abed (90), Millot (88) or Senach (90).

Table 1-a. Detailed description of the method of design

PHASE	SUB-PROBLEMS	OBJECTIVE		EXAMPLES OF TOOLS AND TECHNIQUES USED
ANALYSIS	Process	* Identification of aims, stuctural and functional aspects of both the system and its sub-systems. * technical constraints (Dynamics, safety, production…). * Study of different functioning modes and their effects.	1	• Normally functioning system analysis methods, a SADT, MERISE (Tardieur et al., 89), Fluence diagram (Sinclair et al., 65). • Degraded functioning system analysis methods, as : FMECA = design analysis procedure for failure mode, Effects and Criticality Analysis (FMECA, 67). FTM = Fault tree method (Robert et al., 81).
ANALYSIS	Prescribed tasks	* Operator's tasks definition, according to different operational context of the process and to its functioning modes.	2	• Analysis of data issued from step 1 • Work analysis
ANALYSIS	Assistance needs	* Identification of software aids, able to increase operator's efficiency and to decrease his workload. * Definition of an hierarchy of failures that lead to an operator intervening. * Definition of requirements in term of information prediction.	3	• Analysis of data issued from the step 1 • Operator's needs collection techniques if the process exists
ANALYSIS	Real Human operator limits and resources	* Knowledge and experience level function definition. * Make a study of different terms used by operators. * Make a study of tools prefered by the operators.	4	• Operator's data collection techniques • Human reliability analysis and evaluation techniques (see Swain & Guttman, 83 ou Willemeur, 88), THERP : Technic for Human Err Rate Prediction (Swain, 64). SHERPA : Systematic Human Error Reduction and Prediction Approach (Embrey, 86).
MODELLING	theoritical Human operator limits and resources	* Description of cognitive mecanisms built by the operator to perform his different tasks. * Make a study of fundamental Human operator characteristcs	5	• Cognitive task analysis techniques (Hollnagel, 8 Norman, 86). • Problem solving model of Rasmussen (80; 83). • Books on ergonomics
MODELLING	Human operator Model	* Building problem solving trees that describe different steps used by an operator to solve a specific problem. These trees differ according to operator knowledge and experience.	6	• Analysis of data from steps 4 and 5 • Using Artificial Intelligence techniques such as : object, rules… • Modelling tools Petri network (see Abed, 90 ; A et al. 90).
MODELLING	Assited task model	* Building a tree that describes different tasks performed by an operator according to different process operating modes * Considering different assistance tools.	7	• Analysis of data issued from steps 2 and 3 • Using Artificial Intelligence techniques such as : object, rules… • Modelling tools Petri network (see Abed, 90 ; A et al. 90).
MODELLING	Process Model according to assistance requirements	* Building a process description as a set of objects that describe different sub-systems and variables, as well as the relationships between them. This description depends on the assistance technics (diagnosis, prediction…)	8	• Many modelling approaches exist in litterature : reductionist approach (Raulefs, 87), the confluenc method (De Kleer, 84), the process theory (Forbu 84) …

Table 1-b. Detailed description of the method of design (contd.)

PHASE	SUB-PROBLEMS	OBJECTIVE		EXAMPLES OF TOOLS AND TECHNIQUES USED
SPECIFICATION	Presentation mode and Graphical attributes	* For each operational mode and for each component, an ergonomic choice of presentation modes and graphical attributes. * Respect of operator's habits.	9	• Using guide on ergonomy (Scapin, 87; Mac Cormick, Sanders, 85 ; etc. • Using formal assistance tools of presentation mo choice : see Moussa et al., 90 or Kolski, 91. • Intervention of expert in information presentati
	Chaining views "intelligently"	* Definition of how to "intelligently" prepare and chain views according to different process modes operator performed tasks and experience : Building a Man-Machine cooperation network.	10	• Using Artificial Intelligence techniques. • Chaining knowledge formalized in step 6, 7 and 8
	Specific treatment : prediction, diagnosis...	* Building software modules allowing an operator assistance when performing his problem solving task : calculation, prediction modules...	11	• Calculation algorithms • Using Artificial Intelligence techniques.
REALIZATION	Ergonomic graphical library	* effective creation of different graphical presentation modes * Using existing libraries	12	• Many interface design tools exist, for example : Dataviews, X-Windows, Sl-Gms, ... They are of different kinds : tool box, application framework, interfaces generator,...(see Coutaz, 90).
	"Intelligent" Image Manager	* Realization of a module able to "intelligently" activate the interface according to the context.	13	• Creating a system to use knowledge issued from step 10. • Using Artificial Intelligence technics.
	Specific treatment manager	* Software realization of specific assistance modules. * Connection of these modules to the "intelligent" interface.	14	• Formalizing algorithms issued from step 11. • Using existing tools : Diagnosis expert systems,.
EVALUATION	Simulation	* In simulated conditions * Statical ergonomic evaluation of the interface with operators * Evaluation of operator's performances and behaviours when they use such an interface. * Simulation context	15	• Using operator activities evaluation technics, se (Wilson & Corlett, 90; Abed, 90; Millot, 88; etc..
	Integration into a real application	* same aims but with real conditions.	16	• Using operator activities evaluation technics, se (Wilson & Corlett, 90; Abed, 90; Millot, 88; etc..

We are, at present, implementing an "intelligent" interface that we call the Decisional Module of Imagery (D.M.I.) whose framework we will discuss below.

III. OVERVIEW OF THE D.M.I.'S FRAMEWORK.

The Decisional Module of Imagery (D.M.I.) is a so called "intelligent" interface whose design concerns in particular the sub-problems 1 to 7, 9, 10, 12, 13, 15 & 16 shown in table 1.

The D.M.I. with its integrated assistance tool is shown in figure 2 where it is incorporated into a process control room and overall data acquisition is centralized by the data acquisition module (Kolski et al., 90). Data is accessible by both the decision support system and the D.M.I. and is used by the decision support system for prediction, diagnosis or recovery procedures. This information is transmitted to the D.M.I. which then determines "what" can be presented to the operator, "when" it can be presented and "how" it can be presented.

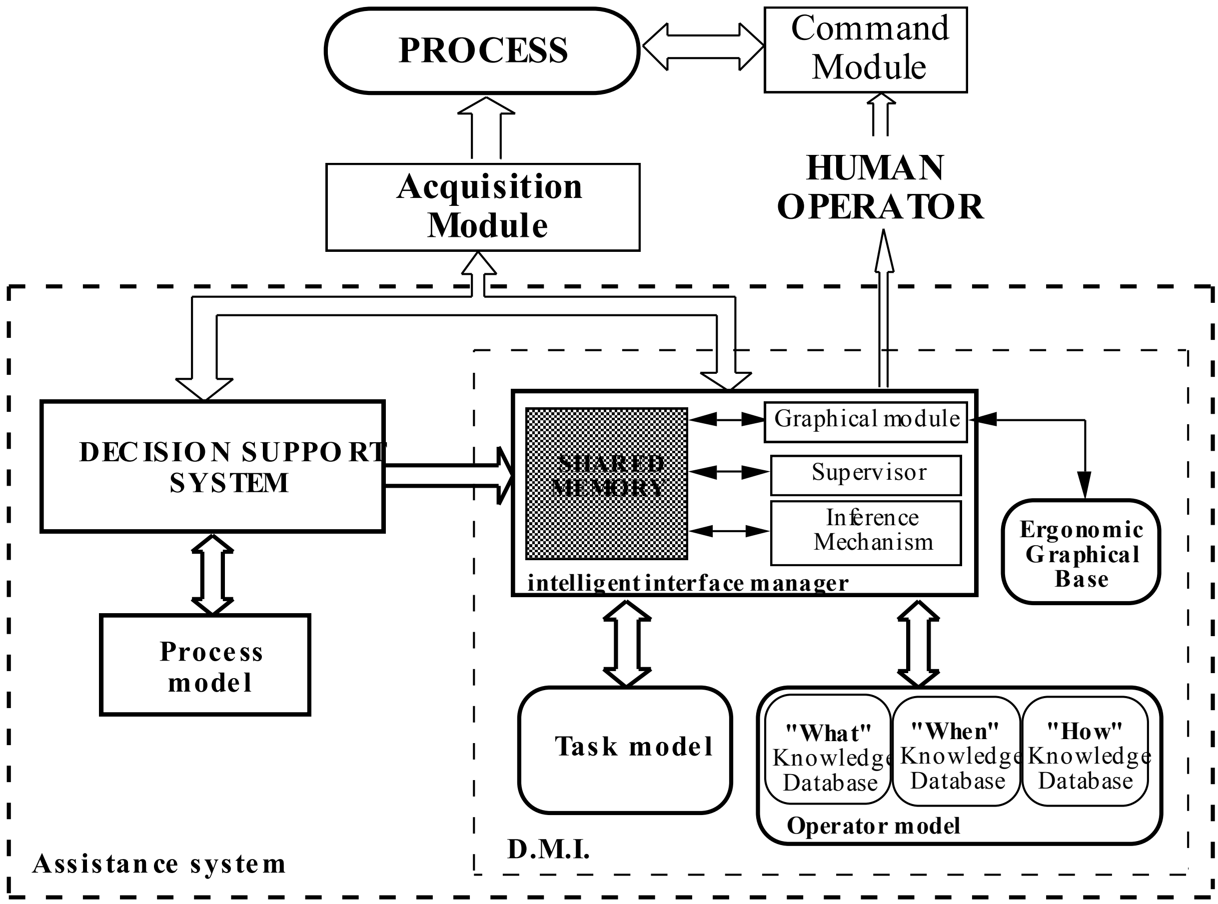

Fig 2. Typical Man-Machine system incorporating the Decisional Module of Imagery

Information selection is based on a model of the tasks to be performed by the operator and corresponds to the steps described below. Alternatively the selection may be based on an operator model containing knowledge of the three ergonomic considerations shown in figure 3 (Tendjaoui et al., 91a; 91b; to be published):

1. **What** to present to the operator (we consider here that "what" contains the "why" by justifying the information displayed);

2. **When** shall we display it;

3. **How** shall we display it.

An ergonomical database centralizes all the presentation modes that can be selected and displayed by the graphics module. This graphics module is controlled by the inference mechanism through a shared memory whose access is controlled by a supervisor. The D.M.I. is developed using the "C" language on a VAX/VMS. The software hierarchy is described in more detail in a paper by Tendjaoui et al. (to be published).

The "What", "When" and "How" problems are described below.

III.1. The "WHAT" problem

The problem concerning what is to be displayed to the operator depends essentially on three criteria:

1. Operator requests: if the operator, when performing his supervisory tasks, requests information on for example, the state of a variable or to justify an action, then the D.M.I. has to supply this information.

2. Operator classification: if the decision support tools perceive an error in the system and propose advice or action, the operator can (i) be in agreement with this advice and act accordingly or, (ii) disagree and request some justification for the advice. The level of detail in this justification will depend on the operators skill level, e.g., a novice operator will tend to require more detailed justification than an experienced operator.

3. The operators task in relation to different process operations: the operators tasks and therefore his informational needs will change according to the state of the process (Rouse, 83; Rasmussen, 1986). Figure 4 shows the different cases where the D.M.I. can intervene and the different messages or displays that can be selected by the operator with respect to the different states of the process. For example, in a transition situation, the operator may need some advice on starting the process, whereas to assess the effects of a corrective action, the operator needs information about the progression of the correction. During an abnormal process state, alarms are automatically selected and displayed, but where an "uncommon" abnormal

situation develops, the D.M.I. can focus on variables that can affect the system's production and/or security by suppressing all information or alarms that do not affect either production or safety.

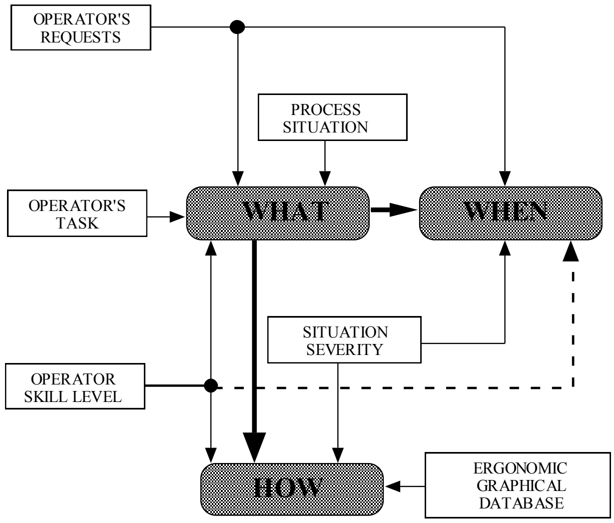

Fig 3. The "What - When - How" concept

III.2. The "WHEN" problem

The problem concerning "when" relevant information has to be presented to the operator depends on the nature of the information that he requested and also on the seriousness of any impending situation. Severity evaluation is bound by production targets and security constraints. To know when the D.M.I. has to display information, we first have to know what this information actually represents (the "WHAT"). For example, alarms are displayed to the operator as soon as they occur, whereas information on action or advice proposed by the decision support tools is only displayed to the operator when requested or when a process situation becomes hazardous.

The D.M.I. has, however, to evaluate the mental workload of the operator in order to determine whether any additional information could be adequately assimilated by him. Mental workload depends on many factors, e.g., the number of potential hazardous situations encountered, their severity, the operators skill level, etc.

III.3. The "HOW" problem

To know how to present a piece of information to the operator, we first have to know what this information represents and the severity of the process fault at that moment. Information is then displayed in accordance with predefined ergonomic modes (figure 3). If several different presentation modes are available to the operator which can be used with the same efficiency, then he can configure the interface according to personal preference. Some examples of "HOW" are:

- To indicate the progression of a variable during the process, graphical curves might be appropriate. They inform the operator about trends in the variables history.

- Colour, red for example, can be used to indicate process status.

III.4. The inference mechanism

All the information described above is presented in rule form (see examples in paragraph IV). These rules are exploited by a data-driven inference mechanism integrated into the "intelligent" manager (Le Strugeon, 91). The mechanism's operation is represented in figure 4. The facts considered by the mechanism are: the process condition, the severity of the situation, the operator's task, the operator classification (or skill level), his informational requests and the previous "WHAT"event. These factors constitute the initial fact database and this data is centralized in the shared memory. The mechanism uses this data for deducing the value assigned to each of the three required conclusions: "WHAT", "WHEN" and "HOW". To verify the validity of these deductions, another database called the "possible fact base" is used. It contains all the acceptable facts, and for each fact its possible values. Naturally, this database is instructed in accordance with the application concerned and its constraints.

It's conclusions are accessible by the supervisor which has to display information in accordance with the ergonomic graphics database containing all the possible presentation modes, such as curve, "star", text, mimic, bar-graph, counter, and so on. All these modes are evaluated by experts in the field of man-machine communication for their suitability and user friendliness.

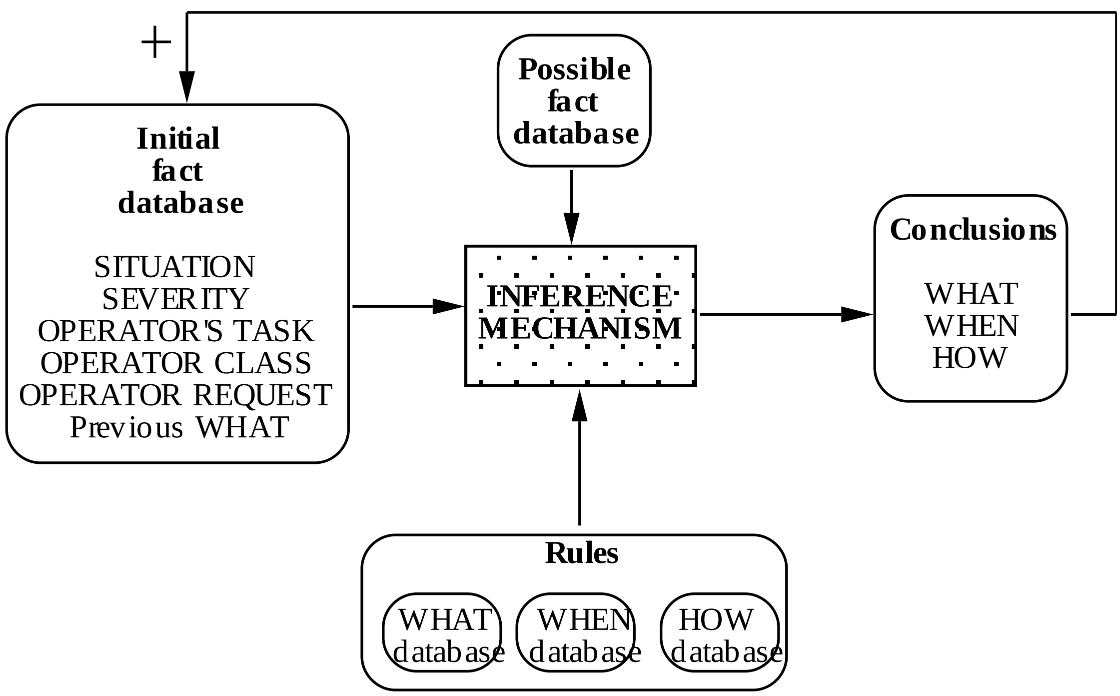

Fig. 4. The mechanism's operation (Le Strugeon, 91)

III.5. Method for constructing the D.M.I.'s knowledge database (Tendjaoui et al., 91b)

This section describes the computational method which is used to construct the D.M.I.'s knowledge database for a given application (figure 5).

- The analysis phase (sub-problems 1 to 4 of the design process) gives an inventory of all possible values of decision criteria used by the D.M.I. for imagery management for example, the degree of severity associated with the process, the process situation and any assistance required by the operator with respect to the tasks he has to perform. This information defines descriptor units characterizing the Man-Machine system; each descriptor is composed of two states (Attribute/Value), for example, the attribute "functioning situation" may be assigned many values such as "Normal", "Abnormal" or "Critical".

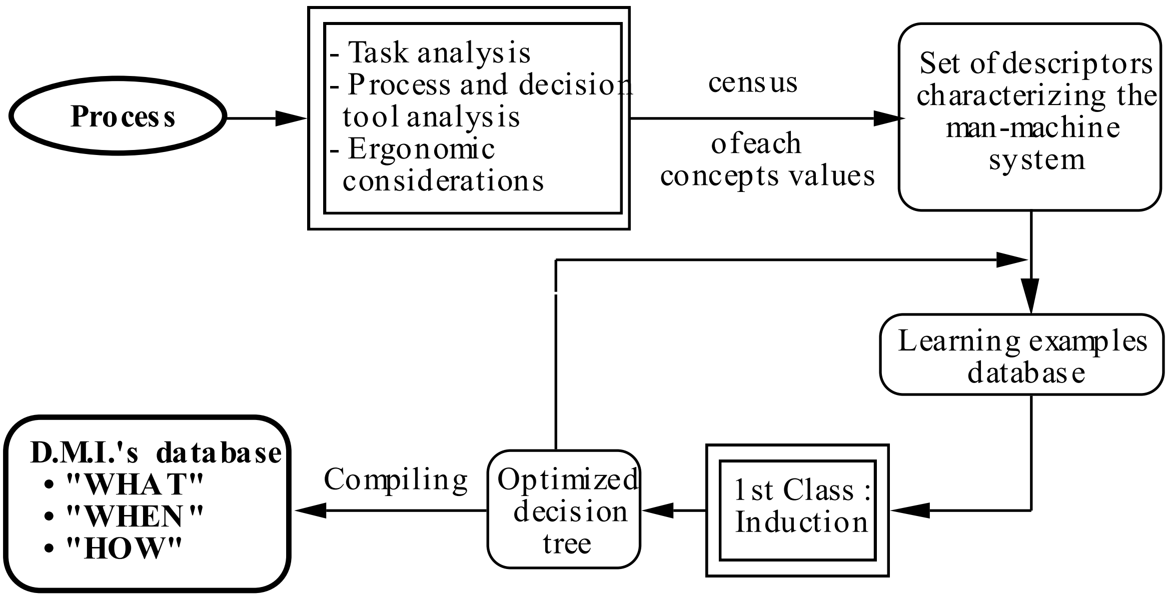

Fig. 5. Method for constructing the knowledge database (Tendjaoui et al., 91b)

- Using these descriptors, we can build relationships between the decision criteria concerning the D.M.I.'s conclusions of "**What** information is to be presented to the operator", "**When** shall we display it" and "**How** shall we display it". During this step an "example database" is created. This example database uses attributes corresponding to the problem being analyzed and each attribute has a finite number of possible values that are mutually exclusive.

• The example database uses information derived from the Learning Machine in order to generate an optimal decision tree. This is created by the Artificial Intelligence Tool 1stClass and is based on the ID3 (Interactive Dichotomizer 3) algorithm which generates a set of procedures that build up into a decision tree using a sample called a "learning group" (Quinlan, 1979; 1983).

• The final step compiles the decision tree so that the D.M.I. can exploit it using production rules set by the inference mechanism written with the "C" language.

Constructing the D.M.I.'s knowledge database in an experimental industrial context is dealt in the following part of this paper.

IV. CASE STUDY

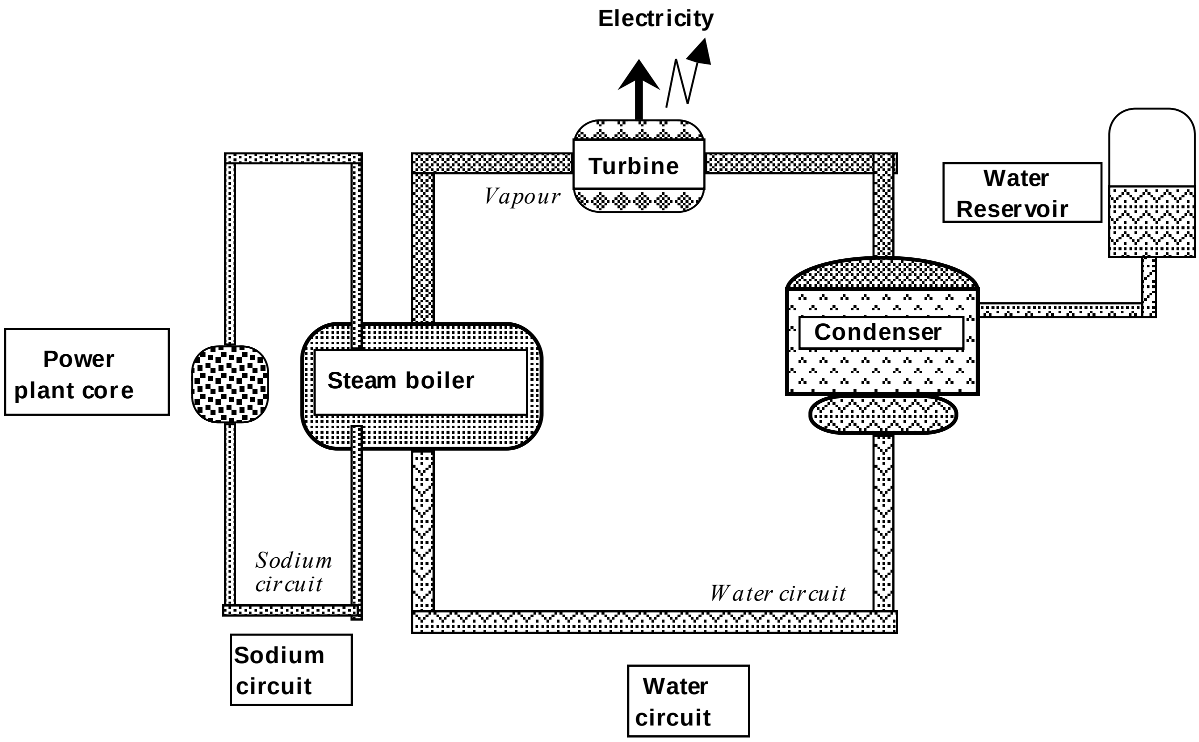

Fig. 6. The simulated process

In order to evaluate the D.M.I., we have developed an experimental platform of a process that simulates the behaviour of a simplified power plant. It comprises two circuits: a primary circuit and a secondary circuit containing a turbine and a water reservoir (see figure 6). Based on this platform we are applying the design process presented in the first part of this paper to implement the D.M.I.'s knowledge database and to integrate it into the control system.

IV.1. Phase 1: Analysis

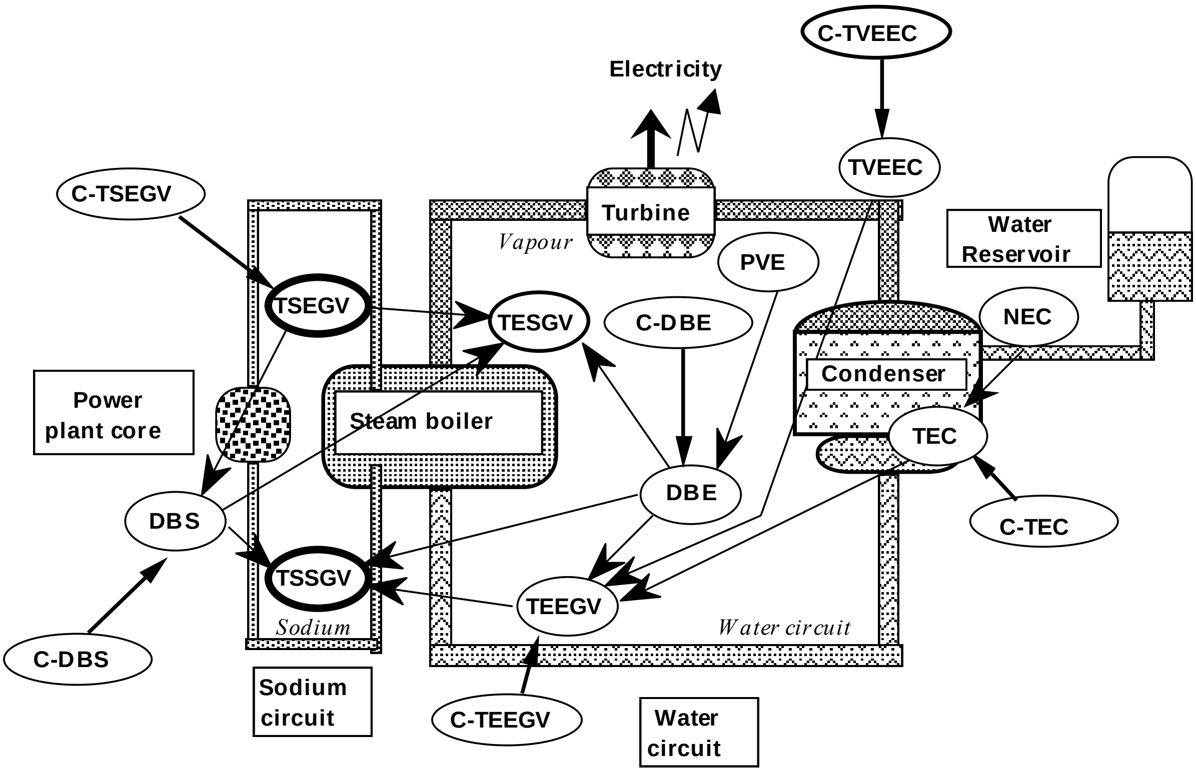

Fig. 7. The location of, and relationships between, variables in the simulated process

Analysis of the process allows us to make a census of principal variables and the relationships between them. Figure-7 shows the 16 main variables that can or cannot be automatically regulated Those variables that can be directly related to system safety or the energy produced are indicated.

The operators main tasks are: (i) to ensure the safety of the system by avoiding all primary circuit malfunctions whilst, (ii) providing constant output. Thus, when a malfunction occurs, the operators task is to compensate for the failure and bring the process back to a normal operating level.Under normal operating conditions his aim is to both supervise and regulate process variable adjustments to optimize output.

According to ergonomical requirements we have outlined several areas of assistance that the operator must be provided with (Vittet, 81; Daniellou, 86; Rasmussen, 86; Taborin, 89):

- structured alarms;

- variable prediction;

- action advice tendered when malfunction occurs;

- justification of such action advice.

As we are working in a simulated process and do not have a "real" operator, we have made the following suppositions concerning operator limits and resources:

- The only role considered is one of "process controller" (Bainbridge, 78) and we have discarded other roles such as "maintenance operator", "process engineer", or "occasional software system user";

- we suppose that the operator solves problems when he compensates for failures and that he is used to working with workstations containing a graphical display, a keyboard and a mouse;

- we suppose that the operator is familiar with all the terms and graphical presentations used by the interface (thus, when evaluating the system, preliminary learning and training sessions will be done).

IV.2. Phase 2: Modelling

We have constructed a decision tree using: (i) information related to the limits and resources of the human operator, (ii) theorical knowledge about the human operator derived from literature and based on the different steps of Rasmussen's model (Rasmussen 80; 83). This decision tree tries to answer the questions: "What" information to present to the operator, "When" to present it, and "how" to present it. This decision tree has to be generic without detailing all the variables that constitute the process. This tree constitutes the operator model (see explanations given in sections III.1, III.2. and III.3).

The general task model assisted by the decision tool is shown in a simplified way in figure 8. Tasks may include: (i) starting the process, (ii) supervising and optimizing the process, (iii) diagnosing and correcting malfunctions, or (iv) shutting down the system (particularly if the situation becomes dangerous).

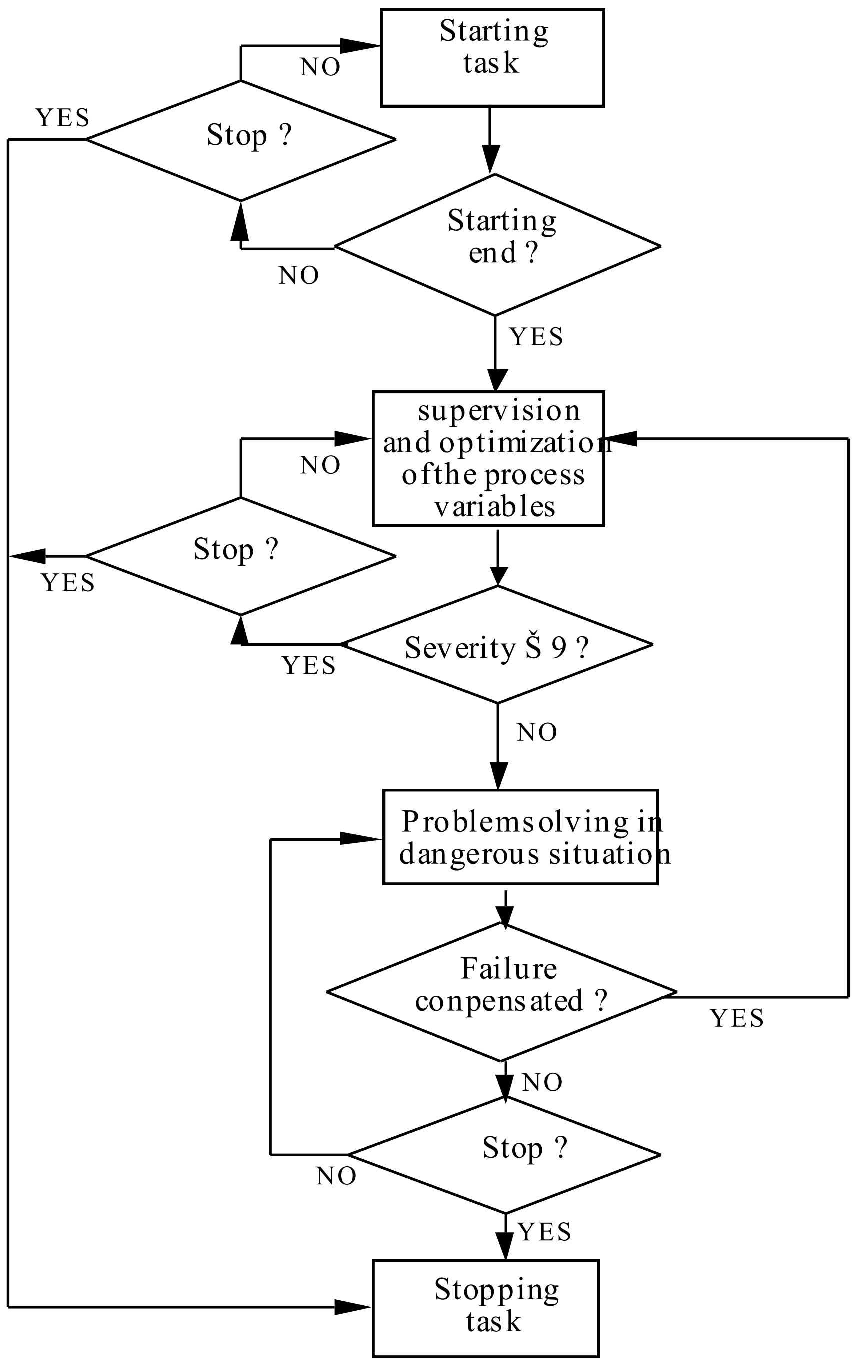

Fig.8. the task model

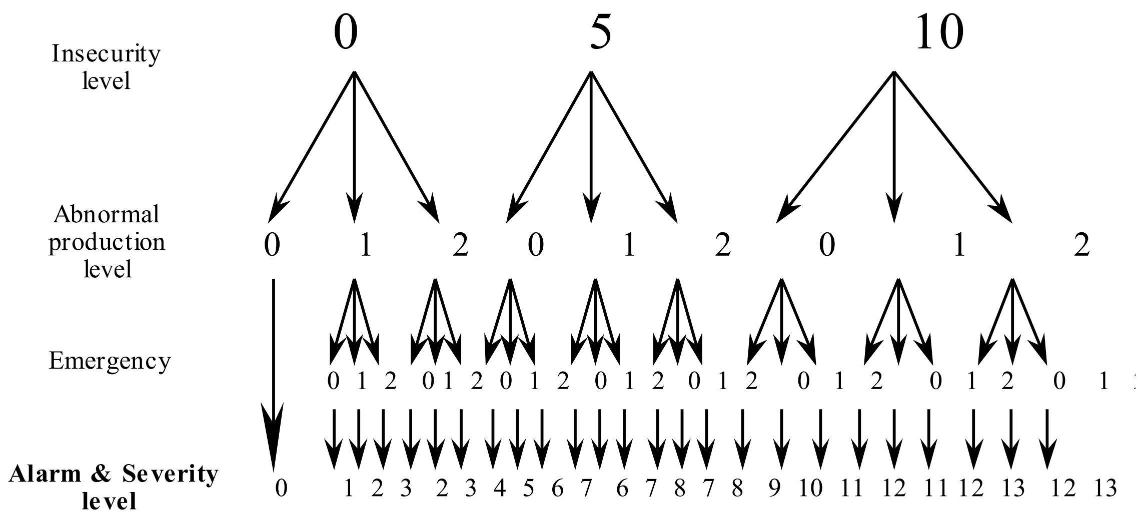

Fig 9. Alarm and severity evaluation levels

In figure 8, we can see the situation severity concept which is evaluated using three different "levels", figure 9:

- System security level: It can have one of the three following values 0, 5 or 10 where the value 0 means that the system safety is very good;

- Abnormal energy production level: It can have one of the three following values 0, 1 or 2 where the value 0 means that energy output production is normal;

- the emergency level: When failure compensation is still possible the assigned value will be either 0, 1 or 2. The 0 value means that the operator has enough time to compensate for the failure. Notice here that time is directly linked to the process dynamics.

These parameters are classified into the three categories shown in table 2:

Table 2: Values assigned to safety, production and emergency.

Value	**Abnormal Production level**	**Emergency level**
0	Optimal	long term
1	under-optimal	middle term
2	Critical	short term

Value	**Insecurity level**
0	Normal
5	Abnormal
10	Critical

It is possible to identify 15 situation severity levels numbered 0 to 14 (figure-9), using the following function:

Severity level:= Degree (Security) + Level (Abnormal production) + Level (Emergency)

This severity level is also used to establish 15 structured screens and to display them to the operator and also indicates to us five process situations (see table 3): optimized, normal, abnormal, critical and non recoverable.

Table 3: Process situation identification corresponding to severity level.

SEVERITY	PROCESS FUNCTIONING SITUATION
0	**Optimized**
1 to 3	**Normal**
4 to 9	**Abnormal**
10 to 12	**Critical**
13 to 14	**Non recoverable**

Finally, we defined qualitative relationships between all process variables. Here, we create a propagation network, where a dot represents a variable, and a link represents the propagation effect from one variable to another. A link is represented by four parameters which are: gain, response time, delay and the variation in way (+ or -). This principle is discussed in more detail by Caloud (88) or Ferray-Beaumont (89).

IV.3. Phase 3: Specification

To specify different representation modes and graphical attributes, we have used both our personal experience in the field of interface design, and recent literature on this subject. These presentation modes answer the question "How to present information to the operator" that was specified in the operator model. For example, displaying a variable in a curve form requires a graphical representation of both static and dynamic sections of this curve.

Where several graphical displays need to be chained together, a human-interface cooperation model derived from both the operator model and the assisted task model is used see figure-11. The model considers the three behaviour levels listed by Rasmussen: (i) Skill-based behaviour, (ii) Rule-based behaviour and (iii) Knowledge-based behaviour. For each of these three levels, the "intelligent" interface will have to provide different graphical means of assistance using knowledge contained in the "What", "When" and "How" databases. The object is to obtain agreement between the operator and the decision support tool when a malfunction occurs and when the operator has to make a decision. Thus, if the operator does not agree with the course of action advised by the decision tool then the interface must be able to explain and/or provide justification of its decision (Taborin, 89; Taborin, Millot, 89). The model presented in figure 11 shows an overview of the communication between the operator and the "intelligent" interface, when a malfunction occurs.

The decision support tool considers the situation and generates a series of structured screens. Knowing both the situation severity and the operator's skill, complementary information can be displayed by the interface for example, action advice, action justification and so on. The operator can agree with the assistance system and act accordingly which can be equated to Skill-based behaviour. However he can be undecided and try to evaluate the situation further in order to make a diagnosis and to take corrective action (his reasoning based on complementary information). If "surface" justification allows him to identify the process situation he can adopt the proposed actions. This behaviour can be equated to Rule-based behaviour and figure 10 shows an example of "surface" justification.

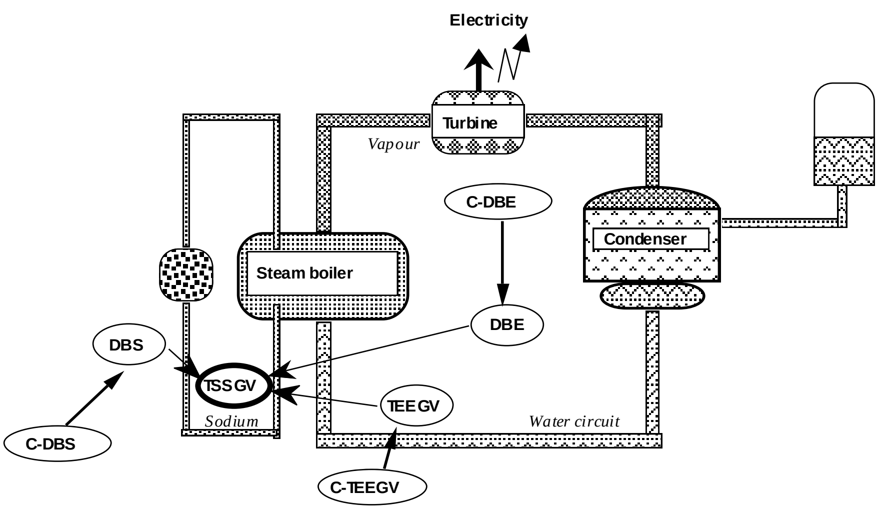

Fig. 10. An example of "surface" justification

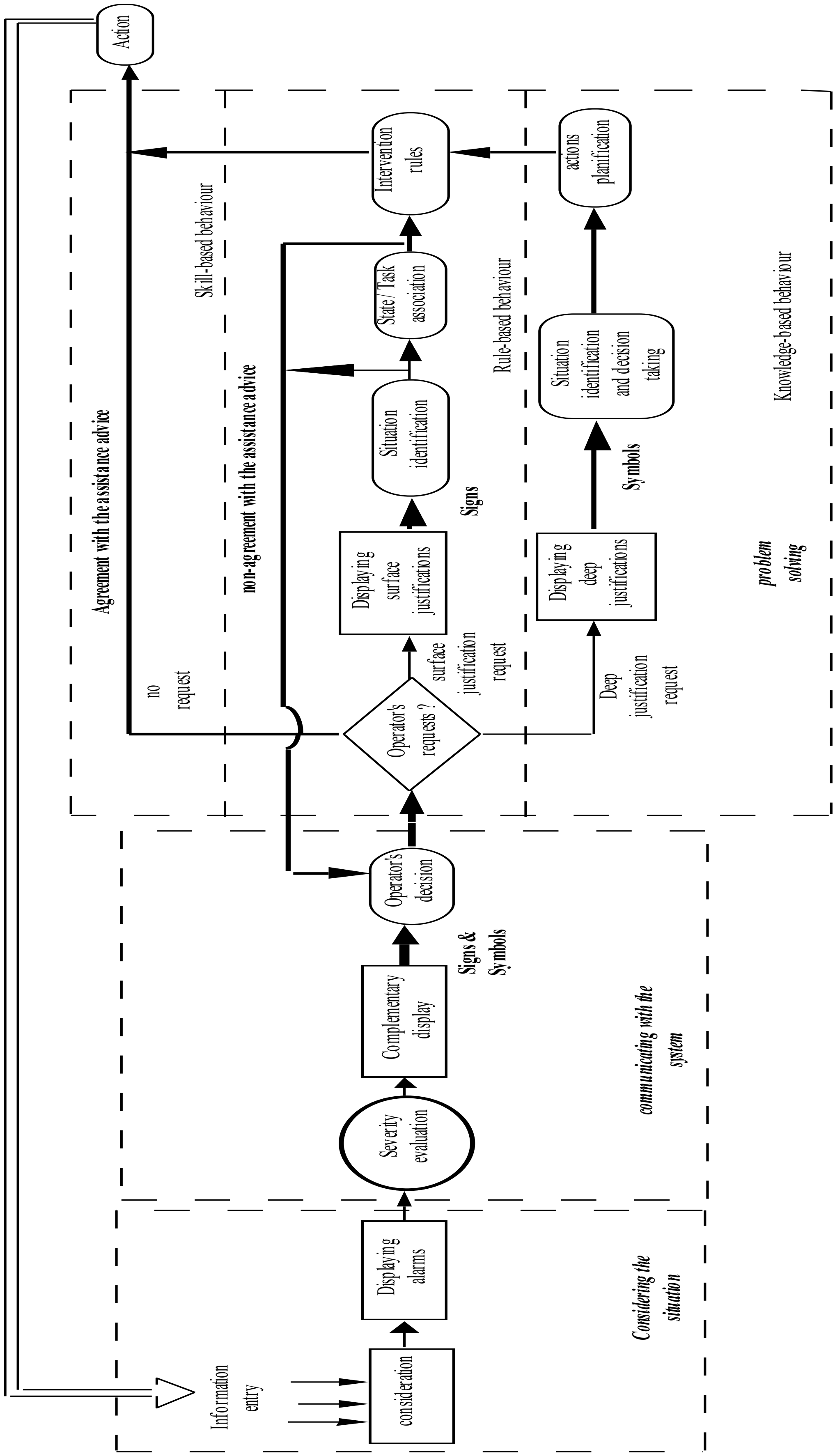

Fig. 11. Man-Interface cooperation model

A third behaviour level, Knowledge-based, exists where the operator uses "deep" justification helping him to make his own diagnosis. Figure 12 shows an example of "deep" justification support: a display curve represents the variables most significant to the prediction made by the assistance system. These variables are chosen and displayed using the following criteria (Taborin, 89):

- to present those variables connected with any action advice given by the assistance tool,

- to present those variables affected by the change of any connected variables,

- finally to present any other variables affected.

A maximum of three variables are displayed at the same time, a variable being represented by three curves (figure 12) - its history prior to the last fault prediction, the current prediction and, its evolution since the last prediction. The prediction time, PT, is indicated by a vertical axis which corresponds to the date for which the process state has been considered by the assistance tool during the last prediction.

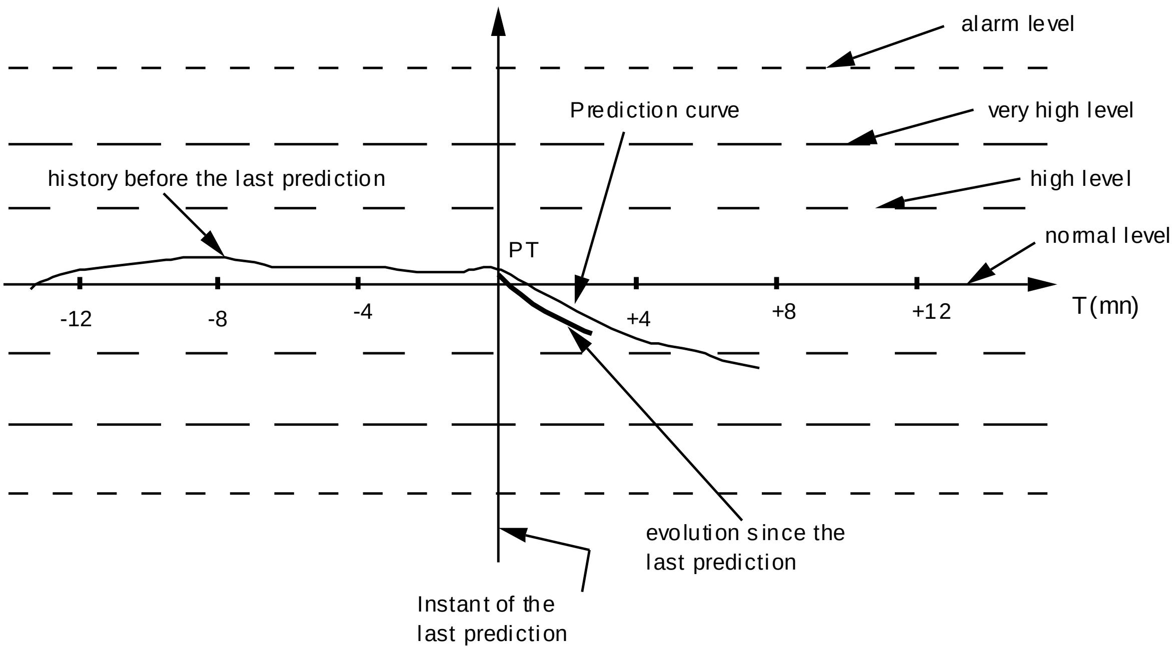

Fig. 12. An example of "deep" justification support

We have to define classical algorithms or use artificial intelligence to specify the assistance modules - for example, algorithms able to perform surface diagnosis or algorithms able to predict variable history and evolution according to the qualitative process model, and so on.

It is now possible to perform an effective implementation of these different modules.

IV.4. Phase 4: Implementation

The realization of the presentation modes and graphical attributes used by the "intelligent" interface was done with a tool called DATAVIEWS (V.I. Corporation, 88), on a VS-3100 workstation. Each display is divided into 5 zones (figure 13). Zone A is used to display alarm and action advice, zone B is used to display text providing justification of actions, zone C - the most important - contains graphical information, zone D is used for dialogue with the I.D.M, and Zone E is used for process dialogue.

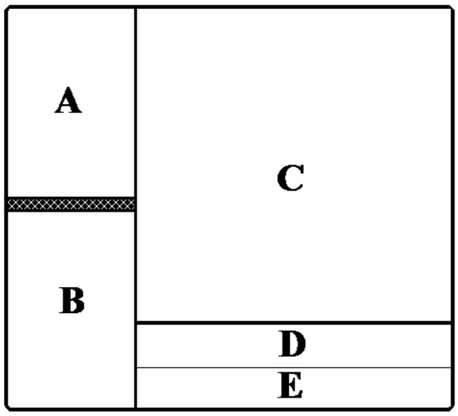

Fig. 13. The 5-zone composition of a display

The "intelligent" imagery manager is developed using "C" language. It incorporates an inference mechanism able to exploit all the production rules contained in the three "What", "When" and "How" knowledge databases. At present, there are 80 rules in the "What"database, 73 rules in the "When" database and 108 rules in the "How" database.

After their creation, these rules were analyzed by the ID3 algorithm (Quinlan, 79), and developed as a decision tree. Below are two examples of the "What" knowledge database. They illustrate the two differing information displays produced when the skill levels of the operators differ. The process function and the level of situation severity remain the same. For each example, the severity value means that there is abnormal energy production but safefy is normal (please see below).

IF situation = Abnormal
and IF Operator Class = Expert
and IF Severity Œ [1,4]
and IF Operator request = No request
and IF Operator task = Problem solving
THEN WHAT:= Wait

IF situation = Abnormal
and IF Operator Class = Novice
and IF Severity Œ[1,4]
and IF Operator request = No request
and IF Operator task = Problem solving
THEN WHAT:= Automatic display of actions advice

Finally, for the specific treatment manager we have constructed a simulated aid tool composed of two separate modules. The first module uses cards containing four types of information: (i) failure identification, (ii) an associated course of action, (iii) surface justification of this action and (iv) deep justification of this action. The second module uses a rapid power plant simulation in order to identify variable trends. Both these two modules are developed with "C".

After all the assistance system modules have been realized we can implement the final design process phase - that of evaluation.

IV.5. Phase 5: Evaluation

This phase is implemented exclusively in the laboratory and all the necessary modules must be integrated into the experimental platform. Our objective here is to compare the operators behaviour with his performance wether an ordinary or "intelligent" interface is being used (figure 14). This comparison is done by using a set of failure scenarios (Tendjaoui et al., 91a). The experimental results will be published at a later date.

We are concurrently integrating a man-machine cooperation model in an industrial process supervisory system, called PREDEX (Gambiez et al., 90; Gambiez et al., 91). This system uses a qualitative model of the process to be controlled (Tang & Schollkoepf, 90). The integration into the PREDEX system of the D.M.I. concept, relative to the adaptation of the interface to both the operator and his tasks, depends on results gained from this experience.

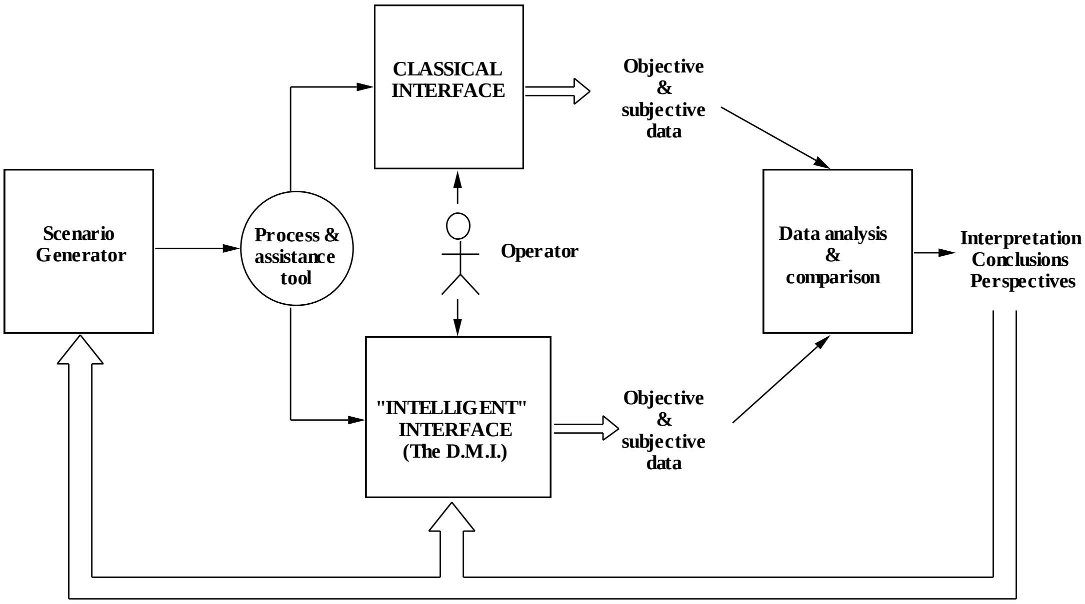

Fig 14. comparison between classical and "intelligent" interfaces

V. CONCLUSION

This paper presents an "intelligent" interface design process in the field of complex industrial processes. This process includes five main phases: (i) Man-Machine system analysis, (ii) operator, tasks and process modelling, (iii) specifying the assistance system incorporating an "intelligent" interface, (iv) implementing the assistance system, and (v) evaluating the assistance system. This process necessitates the construction of three different models: an operator model, an assisted task model and a process model. Using artificial intelligence techniques, it is possible to combine knowledge released from these three models in order to decide: (i) "What" information to present to the operator, (ii) "When" to present it, and (iii) "How" to present it.

We are applying this process to the design of an "intelligent" interface called the D.M.I. the considered application of which is a simplified nuclear power plant. This interface is being implemented onto an experimental platform.

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