A Conceptual Framework for Man-Machine Cooperation in a Supervisory Control Problem

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Keywords: Support Systems, Knowledge Acquisition, Cooperative Assistance System, Human Automatic, Supervisory Function.

Abstract:
This research is concerned with computer assisted design. We will focus on the conception of a system to assist the designer.
We define a conceptual framework to modelise the man-machine cooperation in the knowledge acquisition stage. Our main purpose is to assist the end-user (namely the supervision operator) and we need the supervision operator's skills to achieve this objective. First, we want to provide a library of man-machine cooperation models for problem resolution. Then, we will elaborate a methodological guide to improve the design of such systems.
We applied this theory to a specific case study in supervisory control problem. Here, the operator has to supervise the French National Electric network. He must change the daily planning to correct the situation when disturbances affect a power plant. The characteristics of the problem are: (i) the set of feasible actions is not stable; (ii) qualitative information is present; (iii) actions are valued on N criteria. Our purpose is to assist the operator to build a correction improving the abnormal state of the process. The cooperation between three kinds of models - the model of the end-user, of the problem and of the resolution one - will be the basis of our research. We develop an experimentation mock-up on DEC workstation to validate our approach.

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I) INTRODUCTION

Decision Support Systems (DSS) stem from both Management Information Systems and Operational Research. "Decision Support implies the use of computers to:

- assist managers in their decision process in semi-structured tasks.
- support, rather than replace, managerial judgement.
- improve the effectiveness of decision making rather than its efficiency".

(KEEN and SCOTT MORTON 1978, p.1)

Expert Systems (ES) came from Artificial Intelligence (AI) and could be defined as follows: ES simulate human reasoning process. These two kinds of systems could be seen as completely opposed. The first one is built to assist users, when in the same time the second one is developed to replace them. Nevertheless, ES become more and more complex and more flexible to use. It leads to a second generation of expert systems that integrate a knowledge acquisition module and called Knowledge Based Systems (KBS).

In fact, some authors agree to consider these two kinds of systems as no longer opposed but as complementary systems (see PFEIFER and LUTHI 1987, ZARATE 1991)

Such systems could be improved by integrating the two kinds of techniques. Hence, a new generation of DSS was born: Intelligent Decision Support Systems (IDSS) or Knowledge Based Decision Support Systems (KBDSS). In a general way, the objective of IDSS is to support users' decisions interactively. Users play a prominent part in decision-making. These systems could be seen as support systems.

On the other hand, Knowledge Based Systems are developed for supporting end-users in their decisions. Thus, we have associated the two kinds of systems by giving them the same name: Support Systems. We will consider in this paper DSS, KBS and IDSS as support systems.

Therefore, a difficulty remains in designing Support Systems. The first step of the life-cycle is the bottleneck in the design of such systems. In fact, the major problem consists in the modeling process.

II) SUPPORT SYSTEMS DESIGN PROCESS : A FAILURE

Our goal is to improve the quality of such systems by bringing closer all the parties involved in the design process. We emphasize the fact that three categories of actors are common in the design process of DSS, KBS and KBDSS: the end-users, the experts and the Knowledge engineers. Knowledge engineers are specific actors in the design of KBS and KBDSS but could be linked with
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The actors' proximity is possible by a better communication between them. "The communication is the cement of the organization and the greater the need for coordination and cooperation, the greater the necessity for communication" (BREHMER 1991, p.9). The design process of support systems could be assimilated to an organisation, in the sense that an outcome must be produced in the two cases. Here, communication is costly in term of task knowledge of each other. The agents cooperate via information space (data, beliefs, concept, heuristic) with direct communication and knowing each other or knowing of each other... We assumed that the cooperating ensemble of actors is a relatively closed and fixed collective sharing the same goal and engaged in incessant and direct communication" (SCHMIDT 1991, pp.76-77).

III) A COOPERATIVE ASSISTANCE SYSTEM

For a better cooperation between all the actors, we emphasize the modeling process at the beginning of the life-cycle of IDSS. We can define this life-cycle as follows:

- analysis and modelling,
- evolutive mock-up (model) design,
- prototype,
- in fact, classical life-cycle process.2

This life-cycle process has been defined only for DSS, but we consider that it could be applied to IDSS more generally, to Support Systems.

The modeling process is an important step in the life-cycle of such systems as mentioned before. Our aim is to modelise man-machine cooperation at this stage by introducing a knowledge acquisition module.

Figure 1 shows how this module could be included in the process.

In a more general way, we can define the Knowledge Acquisition module as a cooperative assistance system (CAS). This system could be defined as follows. A cooperative assistance system must:

- take a hand in the end-user's task.
- be justified by the end-user's objectives.

1 for more details see Zarate 1991 p41.
2 for this process see Purviside 1986, Zarate 1991 p36.
A conceptual framework for man-machine cooperation in a supervisory control problem

![Diagram](image)

**Figure 1**

The relations between the parties involved in the classical design process of Support Systems (or IDSS or KBS) are described in figure 2.

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**Figure 2**

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11th EAM, 17 - 19 November 1992, Valenciennes, FRANCE
A conceptual framework for man-machine cooperation in a supervisory control problem

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Figure 2

By introducing a cooperative assistance system in this process we want to establish the relations described in figure 3.

Figure 3

The cooperative assistance system is the link, on the hand, between all the parties involved; and on the other hand, between the support system and the actors. We emphasize the fact that for this system, actors and system are both considered as agents. In fact, the cooperative assistance system itself could be seen more as a process.

For this process, our aim is to build a library of models. A model can be considered as: "a purposeful abstraction that allows to reduce complexity by focusing on certain aspects" (KARBACH et al., 1991). We envisage a model for each category of actors: an end-user model, an expert model, a knowledge engineer model. They can be built with lists of characteristics as for example: actors' hierarchy in the organisation, actors' skills.

Two kinds of models are envisaged for each category of actors: models at a local level and models at a global level.

For the local level, distinctions between the models would be made thanks to all the characteristics concerning the actor himself: his technical skill, his education ....

In the global level, the considered parameters would be: the actor's hierarchy in the organisation, his subordinates .... This library of models will be used in a methodological guide.

Moreover, we emphasize that this approach could be applied directly to KBS. The second generation expert systems integrate a knowledge acquisition module, an explanation module and a knowledge improvement module. The links between the different modules in this architecture can be represented according to Aussenac (1989) as follows:

11th EAM, 17-19 November 1992, Valenciennes, FRANCE
A conceptual framework for man-machine cooperation in a supervisory control problem

Figure 4

By this approach, a new architecture of KBS could be designed as follows:

Figure 5
A conceptual framework for man-machine cooperation in a supervisory control problem

It could represent a new generation of Knowledge Based System: "the third one!". We could apply this approach to a real case that we describe in the following section.

IV) THE INDUSTRIAL FRAMEWORK

There exists an increasing number of areas where a complex semi-automated process is controlled by a human supervisor, including power plants control, air traffic control, brewing and oil refining... (WEIR 91, KOZÁK 92, MILLOT 92). Such complex interactive systems embrace sophisticated control techniques in combination with human operator(s) as a mean of achieving the particular goals of the system. Weir (Op. Cit.) underlines several factors which contribute to the complexity of a dynamic system and illustrates it in the pyramid of complexity (fig. 6, left). This pyramid represents several aspects of complex man-machine systems (fig. 6, right).

We will now try to apply the above hypothesis to a problem encountered by 'Electricité de France' when disturbances affect the power system. The main objective of the power system operation consists in balancing generation and consumption under security rules and in minimizing operating costs. Long-lasting disturbances which occur at any time on the power system generate a production gap towards consumer demands and may make the daily generation planning non operational. In such emergency management situation, the regulation automatisms are insufficient to improve the situation and the supervisory function has to deal with a risky and evolving situation. To
A conceptual framework for man-machine cooperation in a supervisory control problem

fill the gap, manual actions on reserve production units are undertaken by the national dispatching operator in charge of power system generation load balance of 'Electricité de France' (JOURDIN 90).

These aleatory events cannot be treated exclusively by computer: they compel the human operator to perform manual actions in the system near the regulation automatisms (DE TERSSAC 87, TABORIN 89). Moreover, the number of potential actions and the conflictual nature of some objectives make his task complex. The operator must reach quantitative and qualitative objectives with imperfect information distributed in time. And the huge number of possible defaults in nature often leads the operator to face unknown and unexpected situations, in which he has to act following a knowledge-based behavior.

Van Daele and De Keyser (91) consider the decision making in supervisory control as a process involving three different steps: diagnosis (detecting a need for intervention from an estimation of the state of the system), planning (based on this estimation and according to a system target state, to selecting a set of possible actions to carry out) and execution (carrying out the optimal action decided upon in the planning step and evaluating the feedback obtained). But, the search for optimal actions becomes difficult when the problem has different objectives measured in different units, these objectives are mutually conflictual and the decision-maker has different possibilities to reach these objectives. Those points are underlined by Ko (88) and Ligeza (88) as a multicriteria decision in a complex environment.

With (i) the needs of explanation for the operator about the solution and the resolution process, (ii) the changes of the universe and the system controlled over time, and (iii) the incomplete and uncertain knowledge of the system about its environment, the descriptive approach (the OR and MCDM mathematical methods) cannot be used for the modelization. Too formal, such methods require a well structured problem and are useless in front of the information problems encountered. Also, Brehmer and Allard (91) show that the traditional normative decision theory is not suitable. Such a conception ignores both the fact that dynamic decision making involves a series of dilemmas and that they occur in real time.

Thus, we adopted the previous approach by described mixed with a constructive approach in which the decision to be reached is not any longer optimal but satisfying, by organizing rationally the temporal process of decision research (DE BRUYNE 81, LEVINE 89). That is why the system must be compatible with the cognitive aspects of the supervisory operator in interaction with the industrial process. To conceive such an aid, we develop a synergy between 3 models (GANDIBLEUX 92a):
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The user model
To reach the target state of the process, the decision aid process works out a solution interactively with the operator. Such a solution is composed of different actions on power plants to respond to the disturbance by searching the best compromise between qualitative (risks, on long-term impact...) and quantitative (technical constraints, costs...) objectives. Decoris and al (91) have studied the different reasoning needed by the process plant operator to make a decision. They claim that to support such a decision by real aids, decision-support systems have to sustain the operator's reasoning and to follow his own logic, in particular his temporal reasoning and his reasoning about changes in the field. That's why the support system must be designed at any stage for the end-user (DESPRES 92). The critical point is to integrate the end-user model throughout the design step.

The problem model
The system needs to be able to identify and to model the situation disturbed. There is no conventional method coming from the automatic area to identify a sudden failure or an unexpected process fluctuation. Such a failure has to be tackled by the human operator. Moreover, there is no model of normal functioning in which it would be necessary to replace a process after appropriate diagnosis of disfunctioning. The operator has to intervene in situations evolving with their own dynamic, interacting with operator actions. The consequences are that in the case of emergency, the situation requires the operator to build and use two models: a system in free evolution and a model of the effects of their own actions. The system defines global objectives to satisfy (for example, these objectives are to adapt power generation to demand, with the lesser cost...). These objectives are defined in terms of constraints and qualitative criteria to be used with time into the decision process.

The resolution model
To carry on the resolution task, the system uses a set of analytical techniques and problem-solving methods (algorithms and heuristics) to select, evaluate and aggregate criteria to be proposed and used by the Dynamic Multicriteria resolution model (see GANDIBLEUX 92b) in accordance with the cognitive evaluation of the operator. This is an interactive vertical cooperation between the aid support and the operator, where at each step of the correction development, the system proposes an action to be performed to the operator. In order to reach his goals, the operator accepts it or asks some justifications or analyses it with regard to long-term and side effect by using the set of available viewpoints, and then models in criteria. The operator can also change the course of actions and translate his plans into actions. After making
A conceptual framework for man-machine cooperation in a supervisory control problem

the decision for a particular action, the operator must monitor the effect of action and checking at the same time the prognoses of the environment, analyse the evolution of the environment, collecting information or actions at the same time.

To experiment concepts, we develop a mock-up structured in four parts (fig. 7):

(1) the supervisory operator being the decision-maker;
(2) the simulator of the French electricity production network giving values in real-time (automatic regulators, disturbance and frequency);
(3) the scenarii reproducing past real-life situations encountered: they are composed by power plant models, and the characteristics of the dysfunctions;
(4) the supervision system including different functional blocks such as the monitoring of the current state, the diagnosis of the dysfunction, the forecast of the network set point evolution, the identification of potential actions...
A conceptual framework for man-machine cooperation in a supervisory control problem

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V) Conclusion

Some difficulties remains in designing IDSS. In fact, the major problem consists in the modeling process. Our goal is to improve the quality of Support Systems by bringing closer all the parties involved in the design process. We emphasize the fact that three categories of actors are common in the design process of Support Systems: the end-users (see also DESPRE 92), the experts and the knowledge engineers. We assumed that the cooperating ensemble of actors is a relatively closed and fixed collective sharing the same goal and engaged in incessant and direct communication. For a better cooperation between all the actors, we define a part of the Knowledge Acquisition Module as a Cooperative Assistance System. This system is the link between all the parties involved and the IDSS.

In a first phase we want to apply an end-user model into the MRT Support System. In fact, a first aid tool coming from the MRT studies has been done (CARTIGNIES et al 91) follow the classical design process of Knowledge-Based system. This tool was used to develop a general resolution method of the MRT problem and cannot be used in a real supervisory system. We now integrate the real-world parameters and the operator's activities in our studies. That is why we started a second study on the MRT problem taking into account the end-user model in applying the concepts presented here. We are developing the MULCRIDESSS Support Systems in which the decision-maker interacts with the computer-based systems. This support system is conceived on a synergy between the user, the problem and the resolution models. We expect to improve the performances of the operator faced to several alternatives and with a variety of criteria to evaluate, compare and choose actions in real-world emergency situation.

In a second phase we want to carry on this experimentation by developing the expert-model and the knowledge engineer-model, and then improving the end-user model. The end-user's integration in the design process of IDSS now seems to be an obligatory step that leads us to improve the research into the man-machine cooperation field. In this framework, we resort to several methods and methodologies coming from several disciplines: Artificial Intelligence, Information Systems, Psychology... Thanks to this pluridisciplinarity we can design Support Systems which are closer to end-users need.

VI) Bibliography


A conceptual framework for man-machine cooperation in a supervisory control problem


11th EAM, 17-19 November 1992, Valenciennes, FRANCE
A conceptual framework for man-machine cooperation in a supervisory control problem


