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From DSSs to cooperative systems: some hard problems still remain

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Abstract

We review the main concepts put forward by the designers of Joint Cognitive Systems and Cooperative Systems. We claim that all these systems, as well as Decision Support Systems, stumble on the same difficulties related to man-machine cooperation. Apart from technical difficulties coming from present computer inabilities and from psychological or sociological problems, we show that despite the efforts to enrich representations and models, and to understand cooperation, the remaining weaknesses of all the systems from DSS to cooperative systems are due to insufficient representation flexibility, lack of knowledge self-acquisition and learning and, finally, lack of adaptability.

Keys Words: *Decision support systems, Joint Cognitive Systems, Cooperation.*

1 - Introduction

The concept of Decision Support System (DSS) was launched about twenty-five years ago by Gorry and Scott Morton in reaction against the many operational information systems, in existence then, which proved suitable for executing routine tasks but unable to support decision makers in more skillful jobs [3].

During the seventies, DSS concepts evolved from functional definitions: a system that "improves the effectiveness of the decision making rather than its efficiency" [28] to more descriptive and formal definitions [8, 32]. For instance, Bonczek et al. [8] put forward the view of DSS as a problem solver, more or less in the Artificial Intelligence (AI) sense, while Lévine and Pomerol [32, 39] define DSSs as particular Information Processing Systems designed to permit a heuristic search in both spaces of data and models. During the same time, many authors (e.g. Bonczek et al., [8]; Sprague and Carlsson, [44]; Silver [42], insist on the system components (Memories, Dialog interface, Model base) and system objectives [4].

The DSS concept has known some further evolution towards EIS (Executive Information Systems) in which the models are simplified whereas the user-friendliness is increased [41] and now to multidimensional spreadsheets and data-mining tools. Another, more recent evolution, based on Bonczek et al. [8] ideas, emphasizes the role of knowledge systems to extend and include the usual views about models [19]. This stream proposes to think about DSSs as hyperknowledge environments that extend user's mind [18, 46]. Some new developments illustrate these ideas, e.g. Bråmback [12] and Carlsson and Walden [17]. Meanwhile, AI moved almost separately from a view of Expert Systems (ES) replacing people to Joint Cognitive Systems (JCSs) working in a symbiotic manner with the users [52]. This evolution was already visible in the book of Winograd and Flores [51] in which the last chapter is an illustration and defense of interactivity very similar to that put forward by DSS designers ten years ago and ever since (e.g., Keen and Scott Morton [28], p. 2: "The relevance for managers is the creation of a supportive tool, under their own control, which does not attempt to automate the decision process, predefine objectives, or impose solutions").

We will show that the JCS concept that mainly emerges as a new feature of Knowledge Based Systems (KBS), in fact merges different currents and, even if generally not acknowledged is very close to DSS ideas. Our main purpose in this paper is to point out that DSS as well as JCS designers and developers face the same problems and that these problems are mainly concerned with man-machine cooperation and interfaces. In the second section we recall some of the weaknesses of knowledge-based systems. Then, in Section 3, we try to extract the main features of JCSs and to underline the usual views about interactivity in AI. In Section 4, we study the problems faced by cooperative systems. Finally, in Section 5, we stress the difficult issues common to all these types of systems.

2 - Weaknesses of Expert Systems and Knowledge-Based systems

There exists an abounding literature about the strengths and weaknesses of ES and Knowledge-Based systems, see Brézillon and Pomerol [13, 16] and the Journal on Failures and Lessons learned in Information Technology Management Vol. 1 n° 2, for recent reviews. These problems can be divided into two categories :

- knowledge acquisition,
- man-machine cooperation.

On the one hand, knowledge acquisition problems can, in turn be subdivided into "technical problems," for example:

- lack of visual recognition (vision),
- lack of continuous speech recognition,
- lack of natural language understanding,
- burden of manually introducing knowledge (data, rules, cases, etc.) partially due to the preceding inabilities.

On the other hand, we are confronted with the problems related to dynamical, contextual and progressive knowledge acquisition that open out to explanation exchanges, learning and situationality [46].

About man-machine cooperation, the difficulties generally pointed can be split between:

- psychological or sociological reasons relating to the working process and the place and role of human being within this process,
- quality or ergonomomy of the machine interfaces,
- lack of bilateral "understanding" between the user and the machine.

Many of the above problems are actually not specific to ES or knowledge-based systems. The technical problems due to the present state of the art in computer science and machine development are, of course, shared by any artifact. The psychological and sociological components arise in any working context where machine and people must work together. The quality of the interfaces is a problem for any computer system whatever DSS, ES, JCS it is. What may be regarded as specific is, on the one hand, the dynamic al, contextual and cooperative knowledge acquisition and, on the other hand, the lack of bilateral "understanding."

To tackle these two questions, AI researchers are focusing on learning and cooperation. Whereas learning is a very active and promising field that could modify DSS methodology by the introducing, of "learning by doing," "learning by explanation," "case-based learning," we would like to restrict this paper to the second aspect: man-machine cooperation. This notion has received much attention in both AI and decision fields. Again, we restrict ourselves to cooperation between a person and a machine

excluding the problems of interpersonal cooperation and group decision. The question is how to design systems facilitating cooperation between them and their users. The usual answer generally evokes the lack of each other acquaintance between the system and the user and this opens out onto cognitive and psychological issues. At the confluent of these reflections emerges the concept of joint cognitive systems we introduce now.

3 - Joint Cognitive Systems

The expression "Joint Cognitive System" was coined by Woods et al. [52] to stress the fact that neither the system nor the users are able to solve the problem at hand alone. In fact, the search for co-operative cognitive systems goes back to Weizenbaum [50]. Indeed, the introduction of the JCS concept is, among other things, a consequence of the weaknesses of KBSs as perceived by AI community (see Section 2). One of the common views of AI researchers is that the main problems lie at the man/machine interface. This leads to the requirement of a better bilateral understanding between the system and the user. Thus, an important word in the acronym JCS is the word "cognitive." This means that the cognitive aspects of task solving are emphasized. In a broad sense, this implies that the system and the user are able to understand each other when solving a problem. This may be regarded as being utopic because it is unlikely that a machine understands human beings. However, in a metaphoric sense, it entails some very strong requirements about the design of the system. Let us try to underline these main points:

- (1) sharing of the cognitive representations
- (2) agreement about the contextual knowledge,
- (3) ability to follow each other's reasoning,
- (4) capability of exchanging comments and explanations (because it has been observed that explanation is an important mode of interaction [27],
- (5) carrying out a shared control of the interaction [10] or, more precisely, the control of the exploration process remains in the hands of the decision maker [32, 33].

The above requirements are obviously very strong and the question is not whether those properties are, or are not desirable but how to achieve them. The first of the above requirements will probably be fulfilled if the users' cognitive representations are disclosed and implemented in the system. The problem is that, in many human tasks, it is not obvious how to get a comprehensive view of the representations at work in the subject's brain. It is moreover debatable to claim that everything intervening in human can be represented. For instance, about decisions, Damasio [21] has emphasized the importance of emotion and of what he calls "somatic markers" that cannot be represented as such in a symbolic manner. Neurobiologists, such as Berthoz (see Damasio et al.,

[22], and Pomerol, [39] for a survey), also conclude that the brain is not a representation machine.

However many people have tried to partially or totally capture users' representations by using cognitive maps [49, 48, 24]. In the DSS field, several designers introduced various tools, more or less, inspired by cognitive maps, (e.g. Sims and Eden, [43]; Anghern and Lüthi, [5]; Ackermann et al., [2]). However, even if these systems are satisfactory to carry out the task at hand, they still have a very narrow range of possibilities and are unable to change from a level of representation [26, 6, 33] to another with the same flexibility as human mind. Among the cognitive representations a special emphasis must be put on visual ones which are very important in many human activities. This is the reason why many efforts have been made for several years to enrich DSSs with visual functionalities. (e.g. Angehrn and Lüthi, [5]; Belton and Vickers, [7]). The reflection about visual capacities of DSSs is still active (e.g. Zhang, [53]; Loebbecke et al., [34]). The question of the cognitive representation is also crucial in hyperknowledge environments because the system is intended to work in symbiotic manner with the user [46].

The second of the above requirements, about context, is also a matter of representation. Many recent studies emphasize the fact that contextual information is a necessary component for the achievement of any task (see Brézillon and Abu-Hakima, [13] and Brézillon and Cavalcanti, [14] and the proceedings of the conference CONTEXT 97), but the question remains that, in order to make the context accessible to the system and shared between the system and the user, the designer must represent it as computer data. Another difficulty is that the contextual information has no limit [35], whereas designer's resources are limited so that the developer has to draw a frontier between the data indispensable for problem resolution and the contextual data left outside of the system. This raises the difficult questions of the limits of a system. What does the system know? In what context is it safe to use it or not? This last question is very important to prevent accidents [9]. Another approach to the same question is the "situationality problem" [46], namely: how to capture the uniqueness and flexibility of each personal situation with its link to the external environment?

The capability of commenting or explaining each other reasoning is a largely studied issue (see Karsenty and Brézillon, [27]). More generally the question at stake in the above items 3) and 4) is the problem of the cooperation between the user and the system. We are therefore led to investigate the notion of cooperative systems to which we will return to in the next section.

The last point is related to the question of controlling the interaction in an interactive system. We have argued that

the very notion of interactivity means that the user performs an exploration process among many informational states and representation levels whether these states are formalized or not [33]. This exploration obeys the usual rules of any heuristic search and must be controlled by the user. Practically, this implies, interruptability [10], reorientation, resuming facilities at any point and the possibility to have an information on the status of the search (Where are we? What can be done from this state? Etc.).

None of the above points are really new. Nevertheless the JCS concept stresses the difficulty of designing shared cognitive representations and, more questionable, since it is a fundamental AI question, the possibility to represent any brain process in a computer. In fact, this divergence between the representationist point of view and some kind of more embodied knowledge illustrates the two main currents of AI and Cognitive Science. As an example, of the former point of view is the current of KBSs and other systems relying on rules and pre-introduced representations. The other kinds of knowledge are associated to perception, emotion (see e.g. Damasio, [21]), mental associations and, finally, learning and emergence of new knowledge (see Rialle, [40]). Rialle [40] argued for "technologically enhanced cognition," in which the expert and the machine co-operate to result in a new knowledge "emerging" in expert's mind. Therefore, computers become cognitive extensions of the experts. As an example, one may argue that neural networks show such emerging learning because they act as "intelligent classifiers" without being previously fed by rules. This is the reason why many authors designed so-called hybrid systems (e.g., in medicine, Orsier et al. [36] and Aamodt [1] and the literature therein) involving knowledge based systems (rules) and neural networks or case-based modules.

4 - Cooperative Systems

When researchers refer to joint cognitive systems, they want to underline the knowledge continuity and indissociability between the system and the user. In other words, putting the accent on cooperation means that the system and the user complement each other in a symbiotic manner. They have to collaborate or co-operate in order to achieve the task. It is worth noting that the notion of cooperation is not as obvious as it may appear because, when it is possible to automatize, automatic systems work quite well and when it is not possible, it is often preferable to let people continue to handle the task without any computer aid (at least when this support is a non-integrated expert system, (see Brézillon and Pomerol, [15, 14])).

Thus, the field of cooperative systems is limited by totally human tasks on one side and by automatic devices on the other side. When one does not want to cooperate, obviously

one implicitly express the will of working alone, which, conversely, proves that deciding to use a system implies a cooperative mood. Therefore, if the acceptance of the cooperation is a necessary prejudice of system users, what is the interest of introducing the expression "cooperative system"? Any system that is not automatic, is more or less cooperative. We think that the main virtue of the word "cooperative" is that it emphasizes that (1) the system and the user complement each other and (2) there is a dynamic in the cooperation process resulting into better achievements than if the user or the system carried out the task alone.

The first point is especially important because it acknowledges that the system may contain some knowledge (model or data) that really complements the user's skills. This is a perspective that was already discussed in the DSS field where people generally argue for normative models complementing and being "more rational" than the user, while some researchers point out the lack of confidence of the user in such models and his reluctance to use them (see Keen, [29]). It is certain that this question of the user confidence in the system is crucial (see in two different contexts: Lee and Moray [30] and Pomerol and Barba-Romero [37]). There is no cooperation without confidence. It is noteworthy that the complementation of the user by some models, different from those that would naturally be implemented by the user, is antinomic with representation sharing as advocated by JCS designers. On the contrary, representation sharing is consistent with the use of models, in knowledge based systems, whereas, in this case, the representations are not necessarily extracted from the expert's mind. The discussion about the place and role of normative models in cooperative systems (see e.g. in a DSS framework, Keen, [29]) must not hide another discussion about the users' role for gathering and introducing data in the system. In fact, many systems have no sufficient vision and speech recognition abilities and the user plays the role of a perception device (see Brézillon and Pomerol [15, 16]) On the long run, this kind of "cooperation" is generally not accepted by users. One has the feeling that often people design cooperative-systems, only because machine capabilities are not sufficient to achieve automatic devices. This explains why we think that the reverse perspective, advocated by Courbon in Courbon et al. [20] is better: think about DSSs as artifacts in which the user supports the systems in order to become more effective. In other words, designers must acknowledge from scratch that the system needs the user as a partner and not as a necessary device to introduce data. This idea is illustrated by Esaki [25] which show how users (nurses in this case) are really interested in aiding the system to produce better schedules.

Let us attack the second point about the dynamic of the cooperation process. A cooperation process is always evolutive [11] and this raises the question of the system

evolution when the cooperation goes on. In other words, does the system have some learning capabilities. At least is it able to recognize that, after the preceding exchanges, the user has changed and has perhaps acquired some new knowledge from the system? Cooperation also implies conflict resolution and coordination [23]. Thus the problem of the dynamic of the cooperation falls into the problem of learning and adaptation. Is there some adaptative devices that allow the adaptation of the user to the system and conversely ? One can assume that human beings are able to adapt themselves to systems (in fact, this is not always the case and depends on the ergonomics of the system), but it is unlikely that the system adjusts its behavior to the human operator unless it has some programmed learning abilities.

Some authors have made the point that cooperation implies that the goals are shared. Especially in JCSs, Woods et al. [52] said that the system must be goal-driven. This is not so obvious, because many cooperations in the world occur and occurred between people having different goals and knowing it. It suffices that some intermediate goals can be shared whereas the overall goals diverge. Clearly this raises the problem of the goal levels

To summarize, among the new insights introduced by JCSs, we think that the most important are the complementary between the computer and the user and the co-evolution (co-learning) of the system and of the human being during the transactions. The first point again raises the question of the role and place of representations and models, especially normative models, and this question is central in DSSs as well as in any computer system. The second problem of co-evolution and mutual enrichment can be split into learning procedures on the one hand and, on the other hand, user-friendliness and ergonomics.

5 - JCSs, Cooperative Systems and DSSs: what are the remaining problems

As we have just seen, there is no real difference between all these types of systems. They all raise the question of providing a computer support to human beings carrying out various tasks. When the researchers working on these systems reach to practical conclusions, these are almost similar and certainly useful. These recommendations are aimed at defining a good interactivity: explanations, sharing of the representations, explicitation of the context, user control, ergonomics, etc. Besides these very complex problems of man-machine communication and interactivity, it remains the fundamental question of the complementary between the man and the machine. What are the models and data really useful for a task? Can the system impose some models if they are, in some sense, better than those of the user? In this case, how can one maintain interactivity and cooperation? Will a human being accept a system using models he does not understand

or does not trust? All these questions are not new and were more or less already discussed in DSS literature.

The main differences among the three domains, are differences of accentuation (see Table 1). JCS literature is centred on cognitive representations and stresses the difference between symbolic representations and systems allowing some kind of emerging knowledge without the help of pre-introduced rules; cooperative systems focus on the necessary complementarity between the system and the

user, moreover, the designers of cooperative systems should think about designing systems in which the user aids the systems rather than the converse, while DSS researchers are more interested in modeling and development methodologies. However, they all reach to the same practical conclusions about the necessity of interactivity and co-operating [38]. They do not fundamentally diverge about representations and models, but on the fact that they encompass or not all sorts of knowledge.

| | Focusing on | Achievements | Weaknesses |
|--|---|--|---|
| DSS | <ul style="list-style-type: none"> - bring to the DM new skills (normative, models) - interactivity, mainly user control | <ul style="list-style-type: none"> - interactivity (what if) - dissemination of many models | <ul style="list-style-type: none"> - mainly restricted to mathematical or OR modeling - weak connections to data bases - data acquisition problems - lack of complex representation (e.g. visual) - lack of adapting and learning capacities |
| ES/KBS | <ul style="list-style-type: none"> - symbolic knowledge representations - logic reasoning - enlargement of human knowledge that can be modeled | <ul style="list-style-type: none"> - handling unstructured tasks - tremendous widening of computer systems capabilities towards symbolic knowledge - primitive explanations (trace) | <ul style="list-style-type: none"> - knowledge acquisition - lack of learning capabilities - lack of co-operation between the user and the system |
| EIS | <ul style="list-style-type: none"> - friendly interfaces - connection with data bases - simplicity | <ul style="list-style-type: none"> - user confidence - easy to use - processing a large amount of data | <ul style="list-style-type: none"> - restricted to statistical observation without causal models - lack of normative modeling - lack of learning capabilities |
| JCS and cooperative systems Hyperknowledge environments | <ul style="list-style-type: none"> - cognitive representations - representation sharing between the system and the user - system and user each other backing - situation and/or contextual issues | <ul style="list-style-type: none"> - emphasis on various representations - introduction of new models of reasoning - introduction of user modeling | <ul style="list-style-type: none"> - difficulties with some types of representation - lack of representation acquisition - questions about not representable knowledge - adaptability to contextual and environmental changes - lack of flexibility in the representations |

Table 1: Problems and achievements

According to Table 1, let us sum up the problems encountered in human-computer cooperation. In our opinion, there are five main difficulties:

- (1) the interactivity weaknesses due to computer inabilities,
- (2) integration in the working process,
- (3) the representation problem,
- (4) the lack of sensitive experience of the computers as compared to human beings and the consequences about "situationality",
- (5) knowledge acquisition and learning.

The computer inabilities in continuous speech recognition and vision are technical difficulties that probably will be solved one day. However, to date, the fact that it is difficult to have a spontaneous dialogue, in real time, with a computer has two consequences: (1) the burden of data acquisition very often poises on the user, preventing him to use the system; and (2) this obliges the designers to invent special shortcuts and compromises introducing many rigidities in the system.

The problems related to the integration of cooperative systems in real working processes are either sociological or psychological and are beyond the scope of this paper. They sometimes result from the previous computer inabilities.

The third difficulty lies in the fact, that in order to cooperate, the user and the system must share some data, information and knowledge [1]. In the realm of classical AI, this amounts to say that they have sufficient representations in common describing the context, the task knowledge and skills, the goals, and so on. This usual view stumble onto the fact that some kind of knowledge and behavior are implicit, embodied and not easily "representable" (such as image) or not "representable" at all. This problem will probably remain very difficult to handle.

Fourth, about the "lack of sensitive experience of the computers," the two important words are "sensitive" and "experience." We do not expect that computer will acquire some sensitivity in a near future. On the contrary, they can gain experience by learning algorithms. The first objective is then to include learning capabilities, including "learning by doing" or "learning by explanation." Learning is a key capability for a better interaction, it is also crucial to alleviate the data acquisition burden and to apprehend contextual information.

Finally, as it has been recently illustrated by the work of Damasio [21] and some others [22], the expression "sensitive experience" makes sense concerning the decision process in the brain. We guess that this is the same thing for many kinds of reasoning. The recorded experiences are

filtered by our old reptilian brain to reappear through sensitivity. It is also not likely that we will be soon able to endow the computers with some kind of "reptilian brain," this is perhaps neither desirable, nor useful! But we can easily, on a rational ground, value the experiences. In some sense, it has already begun thanks to neural networks and case-based systems. Anyway the lack of "sensitive experience" in the brain sentences the computers to be more rational than their human mates. This is a factor of dissymetry for any interactive system. This will probably generate some troubles, not different from those occurring in any kind of unequal cooperation, for example a thesis director and a Ph.D. student or an employee with his/her boss! Fortunately most people use to overcome these kinds of difficulties. This is a source of inspiration and of hope for the designers of interactive systems.

Last but not least, as is apparent on Table 1, most systems stumble onto the problem of automatic data or knowledge acquisition. Up to now very few systems have overcome the threshold effect. The threshold effect [31], is the necessity to endow the system with a large quantity of knowledge in order to prove some "intelligent" behavior. Also very few show learning capabilities there is in fact two aspects in learning, on the one hand the capability to alleviate the data acquisition burden and, on the other hand the adaptation to contextual and environmental changes.

As is obvious on Table 1, new paradigms and concepts appear to deal with the weaknesses of precedings systems, but none of them has reached a sufficient level in self data acquisition and adaptability, these two issues being linked. Another point is that whereas knowledge representations have gained in complexity, it remains very difficult, for systems, to move from one representation to another or to play with various representation levels. In systems, representation, are still too poor in quantity as in quality. This is the reason many authors are now interested in this question. The focus on visual representation, case-based reasoning, probabilistic networks, cognitive maps, etc. clearly attempts to promote richer representations.

6 - Conclusion

DSSs, JCSs, Cooperative Systems, all these expressions address the same issue: how a computer system and a human being can, jointly, in real time, co-operate to the achievement of a task, so that the resulting achievement be better than if it was carried out by the system or the person alone. The human and system weaknesses and strengths are quite well studied, see Table 1 and Section 2 for system weaknesses and, for human biases, see von Winterfeldt and Edwards, [47], and Tversky and Kahnemann, [45]).

System and human abilities are mainly complementary but the difficulty lies in the cooperation process. The

emergence of JCSs and cooperative systems has permitted to delimit the problem in term of representation, automatic knowledge acquisition and adaptivity to environmental and contextual changes.

The solution of some of these problems progresses, for example data acquisition via continuous speech recognition or image processing progresses with computer performances, whereas representation complexity, learning and adaptability open some new fields to the researchers interested in DSS and cooperative systems design.

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