A Model of Crisis Management System including Mental Representations

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Abstract

We present a dynamic model for Communication and Information Systems of crisis management taking into account the mental representations of actors. This model allows the representation of the intentions and the judgements expressed by the different actors when they exchange information about the situation. It mainly uses auto modifying dynamic Multi-Agent Systems and produces a graphical description of judgements that actors express on the phenomenon.

Keywords

Mental representations, Multi-Agent Systems, Adaptive systems, Meaning, Emergence.

Introduction.

Nowadays, industrial societies are interested in Communication and Information Systems (CIS) which have to manage complex situations as civilian or military crisis [BOR 93]. These new systems use the most sophisticated ways of communication via computers to access to various databases and to exchange information in order to generate tactical and strategic decision. They allow the co-ordination of numerous engaged professionals and very large technical resources: they are complex systems.

The professionals that manage emergency or crisis situations have explicitly asked for a new kind of Information System in European research projects [STE 94]. Their analyses clearly emphasise that the effective knowledge of the decision processes and the mental representations of situations is essential and that if it is left aside, the management of the situation will be badly handled. We may imagine, using new models and based on the most recent powerful ways of communication, a new approach for the CIS. This approach is based on the representation of the decision process itself and the representation of actors' behaviour during crisis encompassing a classical Information System.

As a system, this CIS asks three questions [WAL 77]:

1. What kind of relationship between the system and its environment allows the definition of its autonomy?
2. Is this system made of well-defined and stable subsystems? Does the aggregation in a homogeneous set guarantee the whole cohesion?
3. Does the system, which modifies itself not regularly, have any kind of permanence.

For CIS, the notions of environment and subgroups are fuzzy because exchanged information allowing decision are not complete, not well-defined and not well-understood. CIS must allow the generation of irrational decision of human operators. They have to take into account what the operators think, what their decisions and mental representations are, with intentionality and engagement. These systems aggregate non homogeneous active parts including distant and non professional beholders. The structures of these parts are modified in space and time. Finally, it is difficult to build their variable structure on a rigid and hierarchical order, based on perfect quality of exchanged information.

Thus, we can consider that CIS are systems, but in a systemic way [LEM 90]. They are organisationally complex, with many ways to divide them into well-identified parts. Their functioning takes into account the social complexity of the phenomenon expressed by themselves. Mental representations belong to the field of Complex systems because they are always modifying themselves and they include subjective, psychological, social and cultural parts.

Successively, we present the limits of classical IS in crisis management field, the new model and its characters, and the architecture of implemented prototype.

1. The Classical Approach: Static Knowledge.

In the field of complex situations, Information Systems (IS) use huge computerised and sophisticated communication networks. The large bandwidth allows the transmission of multimedia information and lots of data and thus helps in the management of great amount of human and material resources. Such systems are modelled from the consideration of many physical entities classified in categories (institutions, structures, technical wherewithal...). The functional links between these categories are represented as graph models. So the IS represents many characters of the physical world to provide information and plan about physical situations.

In order to represent these physical objects, the IS need large data servers to provide the asking user with the right information at the right moment [BON 88]. The next figure shows the three levels of organisation in such IS.

1. Physical world, Objective entities
2. Space of development of the entities
3. Movement, Organisations, Planification

Fig 1. Levels in the Classical Approach.

These three levels are descriptive of the objective situation. They describe respectively the studied physical field, the relations between its entities and the expected movements of the entities in space and time. Such information can be used to manage predictively the well-informed situations. These IS are computed, asking some important research questions about swiftness access.

But in emergency situations, we need co-operative actions performed by the decisional actors belonging to different institutions (the Police, Firemen, Emergency Doctors, Officials...). Each actor has its own vision of the phenomenon, which is eventually not consistent with the whole set, including contradictions with others actors and lack of structuring. This may create local oppositions between actors and therefore disturb the previous plans. Such confrontation may interfere with the development of the global phenomenon, speed up dysfunction's. This inadequate interference, which may generate and propagate many others, may lead to a real catastrophe: crisis on crisis [STE 94].

In classical IS such behaviours, such not well-structured visions of the world are not expressed because those behaviours do not appear in any levels of the organisation. So, IS can provide many information but may nor express nor prevent malfunctions caused by non-adapted human estimations. As we show in figure 2, the exchanged information between the different entities only takes into account the results of analyses (the named *Reference state*) but never its process of elaboration (the generation of the *current situation*) disclosing what the actors are thinking.

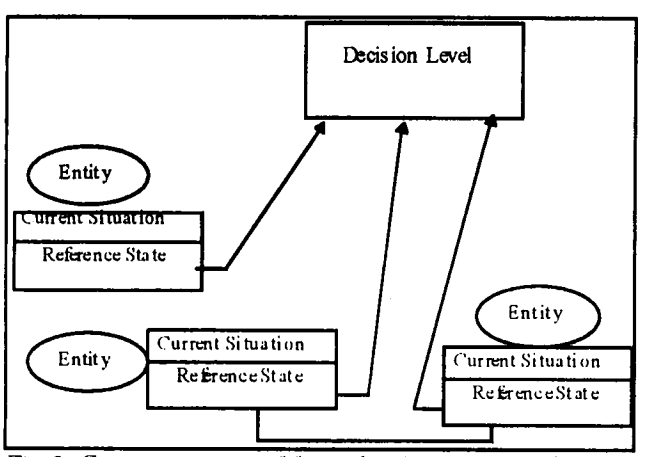

Fig 2. Communication of factual information in classical CIS

Such IS have a permanent structure about exchanged information and they do not really change when the meaning of situation changes for users. They adapt the information they provide to the different actors with difficulty, according to their frame of mind. Indeed, the most important information should not be the same according to the current situation and to a particular actor. In the present case, the system should adapt itself to the actor's situation, to the perception of the actor's situation, in order to help him or her or her but let him or her take his or her own decisions. So, we propose additional layers which allow the actors to express a part of their personal opinions and judgements about the phenomenon. Adding such a layer introduces the so-named phenomenological approach.

2. A Phenomenon Based Approach: The Mental Representations.

A phenomenon based approach is different from the classical one. Indeed, the classical approach is like problem resolution. It tries to plan, to foresee, to organise the situation to prevent the crisis to come. The phenomenological approach takes into account the actors' behaviour and how the reference states (Fig. 2) were explicitly generated by actors. It continually structures the domain and after the knowledge of subjective characters, after negotiations, it will be possible to plan co-operative actions and to take the good decisions. In this way the system must adapt itself to the current phenomenon and to the current perceptions, taking into account at the same time the characters of mental representation the actors express through speech acts [SEA 69] and the generation of their decision process. They are adaptive systems.

In order to create such a system, we have to include some subjective characters like opinions or judgements around exchanged communications. We qualify as *Complex Systems* [CAR 96] such reactive and adaptive systems. They are mainly founded on the expression of human point of view about the current situation and not only on a pre-defined schema of a foreseen situation.

2.1. Communication and Information Complex Systems.

We represent in the figure below the six levels of modelization of such Communication and Information Complex System (CICS) which are the organisation levels for complex systems [LAP 92]:

1. Physical World, Objective Entities.
2. Space of development of the Entities.
3. Movement, Organisations, Planification.
4. **Information Communication.**
5. Values, Symbols, meaning of the phenomenon, intentions.
6. Rules of the social game, power relations, emergence of the global meaning of the phenomenon.

Fig. 3. The six levels of a CICS.

The three first levels belong to the field of the classical IS (C.f. Fig. 1), the fourth allows the dynamic organisation of the previous as in the classical CIS. The levels five and six belong to the social, psychological and cultural field. They can not be represented by a-priori defined structures using fixed primal components: the importance and kind of psychological and social categories they represent depend on the current situation itself. They can not be decomposed into fixed subsystems, for the same reason. Like this, these levels belong to a deep complexity domain. We are interested in these last levels to take into account intentions, opinions and judgements in the communication process, in order to define the decision making.

2.2 The Phenomenological Approach.

The phenomenological approach consists in the knowledge of the whole phenomenon, the real facts and also the mental representations of situations by actors. So, it includes the factual information and the elaboration of the process of decision, the opinions and judgements of the different actors about the different situations and about themselves [BAL 92]. In this approach, the intentionality in the act of information exchange takes precedence over the transmission of neutral information as in classical IS.

In complex phenomena, the managed situation is vague, changing with a lot of contradictory aspects. The phenomenological systems change their own internal structure to deal with the situation, thus reflecting in their internal organisation the meaning of the phenomenon felt by the different actors. This is a structurally variable system because it needs to be very reactive to the operators' feeling. So, to take into account the intentions and judgements of the actors and to make the system to be reactive, we elaborate some hypothesis and some choice about its architecture.

In this way, the general architecture of CICS is based on a distributed structuring system aggregating many communication nodes. The communication nodes are entities representing headquarters of the different institutions. They are made of communication modules allowing in a first part many classical links to Geographical Information System or Data Bases providing factual information to headquarters and in an other part allowing the expression of the various opinions about situations, the elaboration of the mental representations of actors about this situations and also the elaboration of the decision process. These different representations provide the characters of the mental representations about every one.

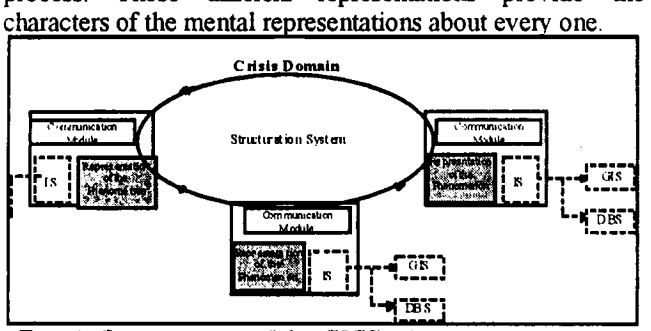

Fig. 4. Organisation of the CICS of crisis management.

3. The Hypothesis at the Ontologic Level.

We saw in 2.2, that the levels 1, 2 and 3 describe the objective situation. These levels are processed by the communicating information level (so named Level 4). We make the hypothesis that the levels 5 and 6 can be represented by some system's inner entities. These levels constitute a specific domain, expressing subjective, social and cultural aspects of the organisation in progress. They are above the four previous ones and alter their structure. This is the first hypothesis of self-reference. They can not be represented, in the whole system, by functional pre-defined categories: each character in these levels, is mainly an *act of communication*. It means, that each communication is wrapped by virtual entities representing the categories of meaning of the communication. This set of entities qualifies the communication and modifies physically a part of the structure of the system itself: they are effective software actions.

So we express categories in levels 5 and 6 with acts of communication. The characterisation of the phenomenon according to the different actors is represented by the variability of situations, opinions, judgements, points of view. The representation of this characterisation in the system will be a structural modification in space and time, wrapped communications. The main hypothesis is that plastic model and plastic software structures are better to represent variable phenomena.

The only model which allows such a plastic representation is a dynamic and hybrid multiagent system [KOR 96] [CBD 96]. We represent the different subjective characters of the communication by a lot of agents, the whole forming a *multiagent landscape*. The behaviour of these agents, their internal transformation and their communication realise spatial and temporal organisation of level 5 and 6. The global characters which can be found in the organisation of the multiagent system (MAS) are *emerging characters* [FER 95]. Thus, those agents with their own particular behaviour may disturb the organisation of the system and make it self-reorganise to exhibit new emerging characters [MAT 80].

In MAS, expected or unexpected structures may appear. We make the hypothesis that emerging structures express the meaning of the communications in the system. This emerging structure represents the accurate views about the different perceptions of the phenomenon elaborated during communication. Because the system is dynamic, the whole emerging structures change according to the evolution of the phenomenon. So the agent structure and its evolution reflects the organisation and the evolution of the phenomenon itself.

4. A Model of Dynamic Hybrid Multi-Agent Systems for the implementation.

The structuring system wrapping communication is represented with different MAS. The architecture is divided in three parts.

1. The first part represents the communicational network between actors (headquarters). Actors mean different entities like individuals, groups of individuals or

professional institutions (the Police, Firemen, Emergency doctors,...). Each entity is a node of the communicational network [CBD 96] and is displayed as a physical actor. This actor dialogues with others through a personalised interface according to specific protocols. This first part corresponds to the classical IS levels.

2. The second part describes the intentions the actors may explicitly express during communication. At this level, we are trying to describe the actors' intentions and opinions about personal and co-operative situations and decisions about the phenomenon. This part is the representation of levels 4 and 5.
3. The third one draws the expressed judgements' complex shape on the interface of operators, using representational graphics. This part corresponds to the sixth level of organisation.

These three parts are in a loop (Cf. Fig. 5) and are modelized with specific MAS.

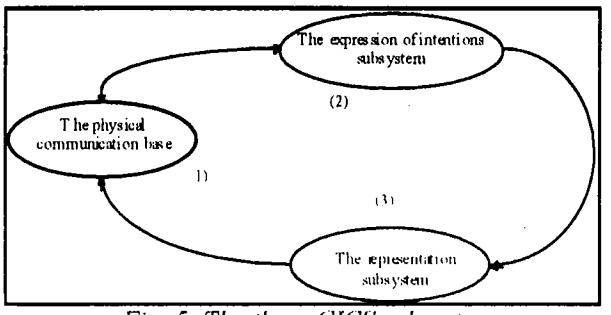

Fig. 5. The three CICS subsystems.

4.1. The CICS Component for Communication.

At this level, we modelize the physical actors, the communication medium and the usual interfaces [KIE 85]. Each physical actor will be described by an agent called *concrete agent*[CAR 95]. This agent is structured by taking into account its functions such as the expected behaviour in its mission. The interfaces must allow a clear and synthetic vision of facts about the situation. It must allow making data requests to information servers and to exchange multimedia information with the other actors [BRO 92]. The actors' communications network is modelized by a MAS with classical cognitive agents.

4.2. The CICS Component for the Expression of the Actors Intentions.

This subsystem allows the expression of the judgements explicitly expressed by the concrete agent about the current situation. Through the interface, each concrete agent has to tell his or her opinions about the characters of the current situation or about other actors coming with communication. These judgements express concrete agent's vision of the world. Each point of view or judgement is taken into account in a set of communication acts, as speech acts [SEA 69], which we call *parasitic agents*. Indeed these parasitic agents bind themselves to a concrete agent, develop and try to alter the concrete agent's neighbours, as shown in the figure 6. These parasitic agents describe some categories of sense about the state of mind of the physical concrete agent (doubt, distrust, incomprehension, trust,...) during each communication.

4.3. The Behaviour of the Parasitic Agents.

The parasitic agents have rational behaviour. Their flexibility, variable number and action capacity are in adequation with the structuring process of crisis management domain. They have goals: surviving and developing according to the communication characteristics. These characters express justifications and reasons of the decision or lack of decision, or opinions about many facts in the evolution of the situation. This is a *dynamic* world of agents. They have their own conquests and confrontations against the other parasites' strategies. These parasites are able to recuperate the concrete agent's judgements in order to impose their own vision of the world to the other parasites. This attempt of conviction is made by increasing the importance of the parasite or by increasing the number of its representatives.

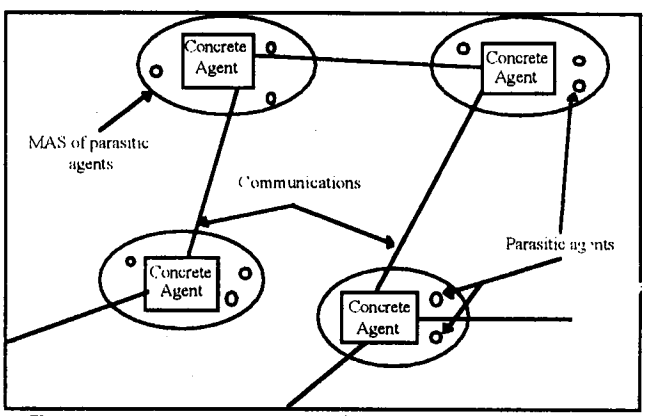

Fig. 6. Parasitic agents enveloping the communication system.

If a parasite grows in relative importance, it means that the underlying concrete agent gives some of its characters a great power (for example, a concrete agent may *strongly* doubt). If the parasite increases the number of its representatives by generating clones, it means that the character is widespread. (a lot of concrete agents doubt about decision or an agent doubts about many things). Both methods of the parasite's development are not independents. We can reasonably think that if a doubt is spread; it will become locally important. Similarly, if a doubt is important locally, it will have tendencies to spread among concrete agents.

A parasite agent has several ways to increase the number of its representatives. It may generate clone, it means a exactly similar parasite of itself. It may also generate a richer parasite by grasping some characteristics and functions from other parasites (generalisation by partial mutation) or a less rich one (specialisation). It may, at least, merge with one or several other parasites (global mutation), adapting its behaviour to the characters of the communication.

4.4. The Emerging Meaning of the Phenomenon.

The previously defined agents allow the expression of the local meaning for each communication in an act of communication. The set of the MAS bound to each concrete actor allows the expression of the whole meaning of the phenomenon. This meaning is generated by *emerging* structures on the set of MAS. For this, we have defined the notion of *algebra of agents*, that is the operation on MAS allowing the emergence of new general agents. This is an important point in our work, where we study the coherence and stability of MAS expressing global sense.

The goal is to have a structural and immediate connection between the set of actors' ideas and the landscape of agents. This notion is central in the model and understood as a real new form of meaning, expressing the synthesis of particular forms (the parasitic agents) around the different concrete agents.

The characters of the MAS, the characters of parasitic agents and their evolution identify the situation in the whole system among three possible states: Initialisation of a global meaning, Deliberation towards a global meaning and Decision towards this meaning. The structure of emerging agents is of the same kind of the parasite ones, with double structure of transition network, expressed fitness.

4.5. The Global Representation of the Phenomenon Subsystem.

The modification of the interface of concrete agents by parasitic agents express a local perception of the phenomenon. The subsystem of global representation of the phenomenon analyses the landscape of parasitic agents to exhibit a *morphology*. It describes the whole set of concrete agents' opinions, judgements and intentions about the perception of the phenomenon. We assume that the representation (thanks to a geometrical shape) can express the global meaning of the phenomenon.

The representation subsystem is, also, modelized with MAS, but using reactive agents [FER 95]. Each reactive agents try to gather communicating concrete agents into *semantically connected components*. These components are aggregated set of concrete agents, according to the semantic proximity. Thus, we have a new topological reading of the communication network. These components gather agents that have some matching characters. They express the notion of group of *common meaning* about the appreciation of the phenomenon. To produce these gatherings, reactive agents monitor concrete agents' judgements and gather those which often exchange some significant opinions. We link these gatherings to semantic values depending on the nature of these judgements. These values may be for instance, confrontation, uniformity, rupture...

In the prototype currently in use, this new topological reading linked to semantic values is represented on a 3D graphic in order to express the emergence of the global meaning of the phenomenon.

4.6 The Simulation Prototype

We have developed in smalltalk a prototype for simulation of communications between actors. In this prototype, each actor has a message window with a communicating box. The actors may send or receive different kinds of messages. When a concrete actor communicates (send or read a message), he or she may express his or her different opinions on the message or on other actors. The opinion encompass the message and is represented by different parasitic agents in the MAS linked to the local actor. The same operation of generation of parasitic agents is realised by the receiver of the message, but with local conditions. In the MAS receiver, the parasitic agents interpret the opinion and act according to it. The figure 7 shows a snapshot of the simulation prototype.

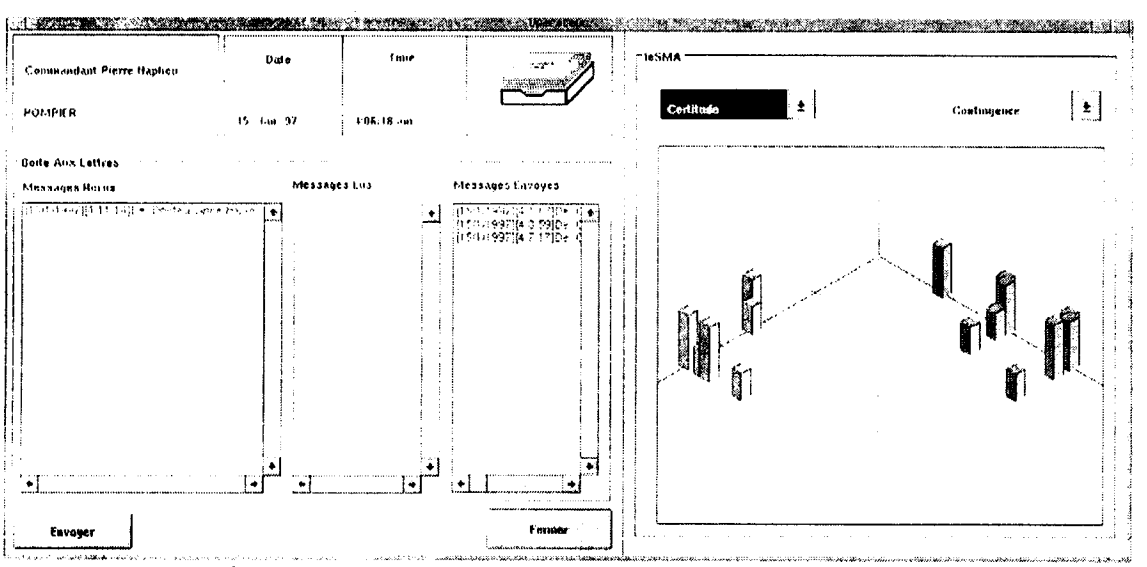

Fig. 7: Operator Window with graphical representation of states of judgments

Conclusion.

A CICS is defined as a plastic system strongly interacting with its environment. It manages situations that we call complex, in which all the actions are taken by actors out of their usual practices. The exhibition of mental representations is the key of good management. As the mental representations are principally variable and not totally predictable, we have to make the structure of the system strongly variable itself. So, we are prevailed to use model with dynamic hybrid multiagent. Therefore, we represent an *organisational memory* of the process of actors' reflection, leading fuzzy and subjective appreciation about situations to well-structured, well-managed field without reduction.

The simulator we have developed in Smalltalk, linking agents and objects, allows the validation of the model, about categories of meaning, pertinence of visual representations and stability of MAS during the acts of communication.

This simulator of CICS is actually extended for effective use on the industrial area of Le Havre (France). In this prototype, actors will exchange subjective opinions about a complex and fluctuating phenomenon to make co-operative decisions. Doing this, some useless confrontations, incomprehension and personal conflicts could be prevented. So, some crisis in the crisis, which are the worst events to occur in an emergency situation, could be also prevented. Such a model may be used in every social organisations which have a computerised communication network when we want to express human actors' intentions to improve the general management.

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