2009 Ninth International Conference on Intelligent Systems Design and Applications

Dynamic Representation of a Situation: a Step of a Decision Support Process

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***Abstract*—A multiagent approach to build a decision support system is proposed in this paper. We think the system may be used in different applications types and is appropriate for complex problems as the risk management thanks to a mechanism of perception, representation, characterization and assessment. We focus here on a first level of this approach that intends to reflect the dynamic evolution of the current situation. The RoboCupRescue is used as a test bed. Experimentations and results are provided and discussed.**

***Keywords*-Decision support system; factual semantic feature; factual agent; indicators;**

I. INTRODUCTION

Risk and crisis management are one of the most complex problems raised by the scientific community currently. The efforts devoted to this research area consists of changing the classical disaster management methods by using new means. This is already realized and accepted as a high priority task by many organisations, governments and companies in Europe and all over the world [3].

We are interested in our works in the risk detection and management in emergency situations. Decision Support Systems (DSSs) are an appropriate solution for this kind of problem, since they are able to complete the knowledge of the deciders and to support them to deal with particular problems. However, DSSs are well known to be customized for a specific purpose and can rarely be reused. Moreover, they only support circumstances which lie in the known and knowable spaces and do not support complex situations sufficiently [5]. Thereby, our main goal is to develop a system that must be sufficiently independent of the treated problem in order to be adjusted easily to different cases of studies. Moreover, we propose an original approach based on a mechanism of perception, representation, characterisation and assessment that enables the system to operate autonomously and to adapt its behaviour according to the change of its environment. We use the multiagent systems (MAS) technology to achieve this objective. In fact, intelligent agents [12] are able to self-perform actions and to interact with other agents and their environment in order to carry out some objectives and to react to changes they perceive by adapting their behaviours.

In order to test and to validate our approach, we need to apply it on several cases of studies. We are working currently at the same time on two different applications: the game of Risk [9] and the RoboCupRescue Simulation System (RCRSS) [7] [10]. The work presented here is addressed to the second one, a brief description of this application and some tests and results are provided and discussed.

II. DECISION SUPPORT SYSTEM FOR RISK DETECTION AND MANAGEMENT

A. Definitions and Approaches

A risk is a concept that denotes a potential negative impact to an asset or some characteristic of value that may arise from some present process or future event. There are many more and less precise definitions of risk. They do depend on specific applications and situational contexts. It can be assessed qualitatively or quantitatively. In our context, we are interested in natural and technological risks. The management of these risks is a large-scale challenge for the individuals and the organisations because of the threats they represent for people and their environment. The risk management may be defined as the systematic application of management policies, procedures and practices to the tasks of establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risk [2]. This process is complex and exceeds widely the human abilities. The use of the DSS in this case is indispensable. Indeed, DSSs are interactive computer-based systems that aid users in judgment and choice activities. They provide data storage and retrieval but enhance the traditional information access and retrieval functions with support for model building and model-based reasoning. They support framing, modeling, and problem solving [4]. In the context of the risks and crisis management, the DSS must insure the following functionalities:

- Evaluation of the current situation, the system must detect/recognize an abnormal event;

978-0-7695-3872-3/09 $26.00 © 2009 IEEE
DOI 10.1109/ISDA.2009.32

- Evaluation/Prediction of the consequences, the system must assess the event by identifying its possible consequences;
- Intervention planning, the system must help the emergency responders in their interventions planning thanks to an actions plan (or procedures) that must be the most appropriate to the situation.

B. DSS Architecture

The kernel is the main part of the DSS (see Figure1) and has as role to manage all the decision-support process. The environment includes essentially the actors and Distributed Information Systems (DIS) and feeds permanently the system with information that describe the state of the current situation. In order to apprehend and to deal with these information, specific knowledge related to the domain as ontologies and proximity measures are required. The final goal of the DSS is to provide an evaluation of the situation by comparing it with past experimented situations stored as scenarios in a Scenarios Base (SB).

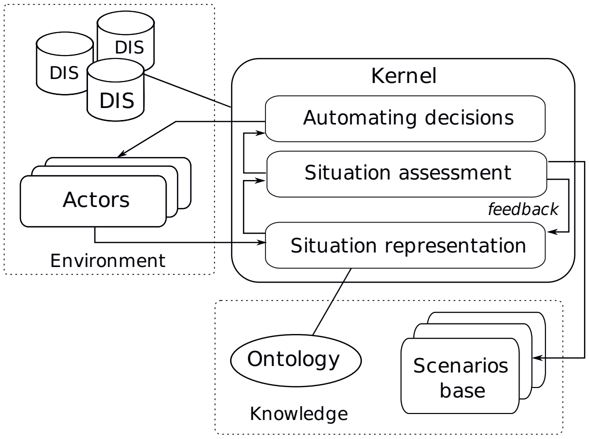


Figure 1. Overall DSS architecture

The kernel is a MAS operating on three levels. It intends to detect significant organisations that give a meaning to data in order to support finally the decision making. We aim, from such a structure, to equip the system with an adaptable and a partially generic architecture that may be easily adjusted to new cases of studies. Moreover, its suppleness makes the system able to operate autonomously and to change its behaviour according to the evolution of the problem environment. As follows a description of each level:

- *Situation representation:* One fundamental step of the process is to represent the current situation and its evolution over time. Indeed, the system perceives facts occurring in the environment and creates, based on these facts, its own representation of the situation thanks to a factual agents organisation. This approach has as purpose to let emerge subsets of agents. The paper focus on this step.
- *Situation assessment:* A set of assessment agents are related to scenarios stored in a SB. These agents scrutinise permanently the factual agents organisation to find agents clusters enough close to their scenarios. This mechanism is similar to a Case-Based Reasoning (CBR) [8], except it is dynamic and incremental. According to the application, one or more most pertinent scenarios are selected to inform decision-makers about the state of the current situation and its probable evolution, or even to generate a warning in case of detecting a risk of crisis. The evaluation of the situation will be re-injected then in the perception level in order to confirm the position of the system about the current situation. This characteristic is inspired from the feedbacks of the natural systems. In that manner, the system learns from its successes or from its failures.
- *Automating decisions:* Outcomes generated by the assessment agents are captured by a set of performative agents and are transformed in decisions that may be used directly by the final users.

C. Application on the RoboCupRescue

We chose the RCRSS in order to apply our approach. The RCRSS is an agent-based simulator which intends to reenact the rescue mission problem in real world. An earthquake scenario including various kinds of incidents as the traffic after earthquake, buried civilians, road blockage, fire accidents, etc. is reproduced. A set of heterogeneous agents (RCR agents) coexist in the disaster space: rescue agents that are fire brigades, ambulance teams and police forces, and civilians agents. RCR agents represent the actors of the environment in our case, they describe the state of the disaster space by sending their perceived information to the DSS.

We focus, in this application, on the fires incidents and their related facts. We intend therefore to perceive and to represent both the fires propagation and the behaviour of the fire brigades.

III. DYNAMIC REPRESENTATION OF THE SITUATION

A. Information Formalisation: Factual Semantic Features

Information reach the system in a generic shape which is the Factual Semantic Feature (FSF). A semantic feature is the minimal theoretical meaning unity that may function as a distinctive element in a relations system. This is known as *seme*. As follows some examples of semantic features: building is +/- burned, object is +/- dynamic… FSFs are semantic features, the noun given to this message content provides an explication to our approach: we stress observed and punctual elements that are the facts. A fact is a knowledge or information based on real occurrences [1], it may be an event, an action, a state change… Each fact is related to an object in the environment. In order to classify these objects, and consequently the types of the FSFs that will be handled by the system, we established a taxonomy. The latter defines the different perceived objects of a dynamic situation, as phenomena, activities, persons, buildings… A detailed description of this taxonomy is provided in [6].

An FSF is composed of <key, (qualifier, value)$^+$>. The key is a unique identifier related to the observed object to which are associated some characteristics, described by qualifiers and their respective values. An FSF has also time and spatial values of the observation. An example of an FSF is the following: <fire, intensity, strong, localisation, building#12, time, 10:00 pm>. This fact describes a strong fire, located in building#12 and which is observed at 10:00 pm.

The goal of the system is to extract the eventful facts of the situation and consequently to deduce potential risks. FSFs are a key concept to achieve this objective thanks to the relations that may have with each other; i.e. FSFs may be equal, close, opposite, or neutral in their meanings. To determine the nature of a relation between two FSFs, they must be compared mutually. Thus, specific proximity measures have been defined in order to compare between the FSFs. We distinguish three different proximities:

- Semantic proximity (P_s) is related to an ontology;
- Spatial proximity (P_e) is computed using formula 1;
- Temporal proximity (P_t) is computed using formula 2.

$$P_e = \frac{4e^{-0.2\Delta(e)}}{(1+e^{-0.2\Delta(e)})^2} \tag{1}$$

$$P_t = \frac{4e^{-0.2\Delta(t)}}{(1+e^{-0.2\Delta(t)})^2} \tag{2}$$

Where $\Delta(e)$ and $\Delta(t)$ are respectively the difference of time and the euclidean distance between the two observed facts.

The total proximity between two FSFs is obtained using this formula:

$$Proximity(FSF_1, FSF_2) = P_s \times P_e \times P_t \tag{3}$$

The proximity measure is included in $[-1, 1]$, so the more near to 1 the proximity is, the similar the FSFs are and vice-versa.

Using the RCRSS in our context allows us to validate the formalisation of information coming from the environment, thanks to the generic structure of the FSFs. Moreover we intend to assess the ability of the system to manage theses FSFs and to analyse the behaviour of the agents that deal with them.

B. Perception and Representation of Facts: Factual Agents

The role of the factual agents is to perceive the entering facts and to represent them over time. The system analyses the general aspect and the dynamics of this representation in order to extract agents clusters that may reveal underlying potential risks.

Each factual agent carries an FSF and aims to manage its evolution. Agents are permanently in interaction and compare the FSFs that they carry with each other. A factual agent may have close agents (positive proximity between the FSFs), opposite agents (negative proximity between the FSFs) and agents with which is neutral (proximity equals 0). It stores its close agents and opposite agents in an acquaintances network which is updated dynamically.

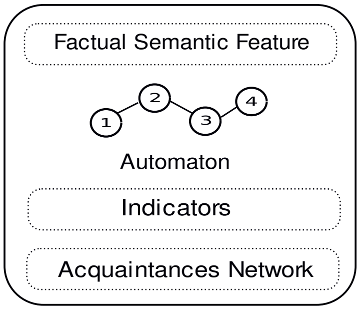


Figure 2. Internal structure of a factual agent

A factual agent has specific indicators to reflect its dynamics. These indicators provide a synthetic view of the salient facts of the situation. They must reflect therefore as much as possible the perceived reality.

The behaviour of a factual agent is managed by an Augmented Transition Network (ATN) [11]. The structure of the ATN is generic, however the conditions and the actions that are related respectively to the transitions and the states, are specific and depend on the FSF type of the factual agent.

IV. IMPLEMENTATION AND EXPERIMENTATION

A. Implementation

Figure 3 presents the class diagram of the representation MAS. The system is made up of three packages:

- *generic package:* is the great part of the system. It includes the main classes as *AbstractFA* and *AbstractFSF*, which represent respectively two generic classes for factual agents and FSFs, other agents classes of the MAS, messages classes…
- *specific package:* includes specific classes as *SpecificFA* and *SpecificFSF* which represent the different specific types of the factual agents and the FSFs;
- *hmi package:* includes HMI (Human Machine Interface) classes and other classes that manage the network part of the system.

Two kinds of factual agents have been developed:

- *Fire brigade factual agents:* they describe facts related to the fire brigade agents of the RCRSS. They belong to the persons (or RCR agents in our case) factual agents family;

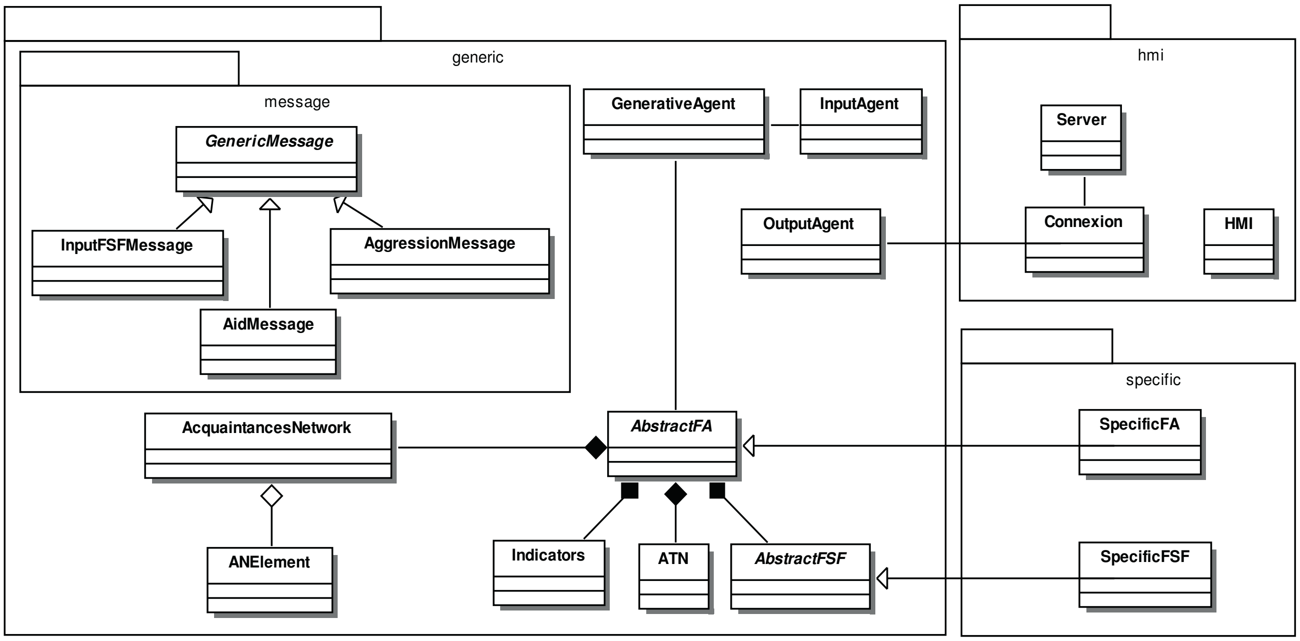


Figure 3. Class diagram of the prototype

- *Fires factual agents:* they reflect the fires evolution in the disaster space. They belong to the phenomena factual agents family.

Fire brigade agents and fires are represented respectively by black ellipses and black rectangles in the RCRSS viewer (see Figure 6). Their related factual agents are represented respectively in black and gray in the table below.

Two specific indicators are associated to each factual agent:

- *Action Indicator (AI):* it represents the position and the strength of a factual agent inside the representation MAS. For factual agents related to RCR agents, AI means the potential of an RCR agent and its efficiency in solving a problem. For factual agents managing phenomena, AI means the degree of damage and hazard exposed by a phenomenon.
- *Plausibility Indicator (PI):* for factual agents related to RCR agents, PI means the ability of an RCR agent to discover new problems in the disaster space. For phenomena factual agents, PI means the solving probability and the worsening impediment of a phenomenon.

The following formulas permit to compute the two indicators:

$$AI = AI' + \textit{Proximity(FSF1,FSF2)} \tag{4}$$

AI' is the old value of AI.

$$PI = \alpha e^{-\beta Y} \tag{5}$$

α and β are two given coefficients and Y is a linear combination of several parameters related to the type of the factual agent.

Figure 4 and Figure 5 show the two ATNs of these two factual agents. Each ATN has four states and intends to reflect the behaviour of the observed object which is represented by the factual agent. Both agents have a *Creation* state (state 1) in which the agent is created and starts activities, and an *End* state (state 4) that means the agent death. More precisely, a fire factual agent is dead when the fire is completely extinguished or when is burned, and a fire brigade factual agent is dead when the hit point of the fire brigade equals 0. Thus, the main states of these two factual agents are state 2 and state 3, in which they are active. A factual agent progresses in this way: $1 \succ 2 \succ 3$ and regresses in the opposite way. The more the agent advances in its ATN, the more it acquires importance and a strength in its organisation.

Both fire and fire brigade factual agents change state when their indicators values satisfy the transitions conditions. The latter are defined as specific thresholds that are fixed according to the type of the factual agent.

B. Experimentations

Figure 6 illustrates a part of the disaster space of the RCRSS and a graphic tool that allows the analysis of the system behaviour and the obtained results. The monitor table shows us in real-time the internal evolution of the factual agents: their creation, their states change, their indicators variation and their death.

In Figure 7, the gray chart illustrates the activities number of the representation MAS during a whole scenario. The

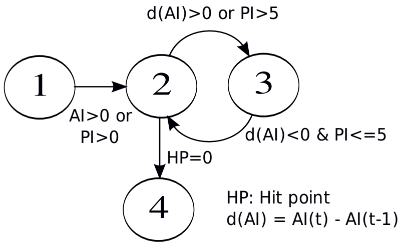


Figure 4. ATN of a fire brigade factual agent

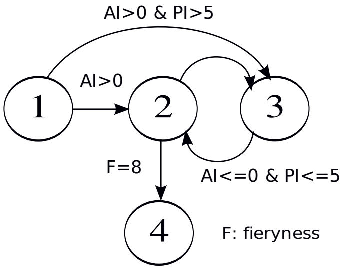
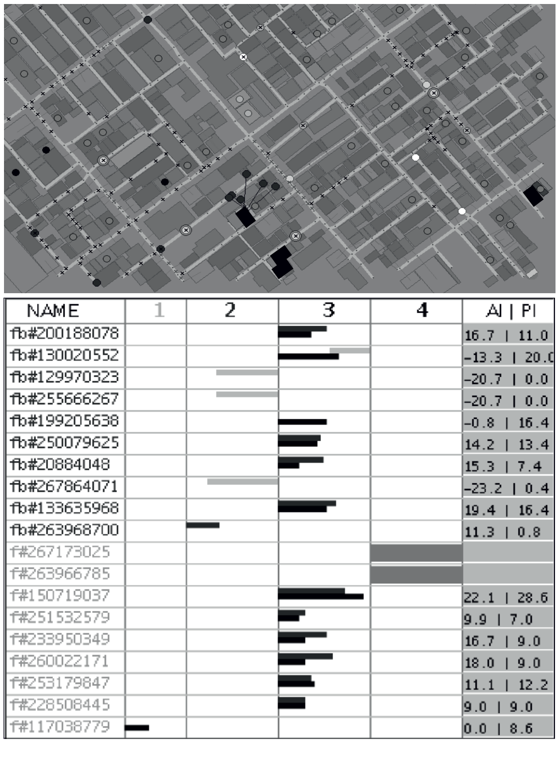


Figure 5. ATN of a fire factual agent



NAME	1	2	3	4	AI	PI
fb#200188078			▬		16.7	11.0
fb#130020552			▬		-13.3	20.0
fb#129970323		▬			-20.7	0.0
fb#255666267		▬			-20.7	0.0
fb#199205638			▬		-0.8	16.4
fb#250079625			▬		14.2	13.4
fb#20884048			▬		15.3	7.4
fb#267864071		▬			-23.2	0.4
fb#133635968			▬		19.4	16.4
fb#263968700		▬			11.3	0.8
f#267173025				▬		
f#263966785				▬		
f#150719037			▬		22.1	28.6
f#251532579			▬		9.9	7.0
f#233950349			▬		16.7	9.0
f#260022171			▬		18.0	9.0
f#253179847			▬		11.1	12.2
f#228508445			▬		9.0	9.0
f#117038779	▬				0.0	8.6

Figure 6. RoboCupRescue disaster space and internal state of the representation MAS

activities include the states changes, the indicators values variations and the messages sent by the factual agents. The gray area represents the fire spreading. The system reacts in a moderate way at the beginning of the scenario, in which the fires are isolated. By dint of receiving more and more information, describing the fires propagation and the mobilisation of the fire brigades, the factual agents react by intensifying their activities. The values and the oscillations of the activities number depend strongly on the behaviours of the fire brigade agents. Indeed, the activities number grows when the fire brigades are fighting fires. Inversely, it drops when the fire brigades are potentially far from fires or are searching new ones. To summarize, we can say that there is a peak of activities when there is a high level of risk and emergency, due to the rapid spreading of the fires and the struggle of the fire brigades that try to restore the situation.

At the end of the scenario, the system knows an evident bending result of the fires extinction. The factual agents become less significant since there are not important facts related to fires that come stimulating them. However, the system still in warning state in order to alert every notable change in the environment. We may notice this at the 63^{rd} second of the simulation, when a fire reappears suddenly. The system reacts immediately to this fact and resumes its activities, then it becomes again stable after the fire were put out.

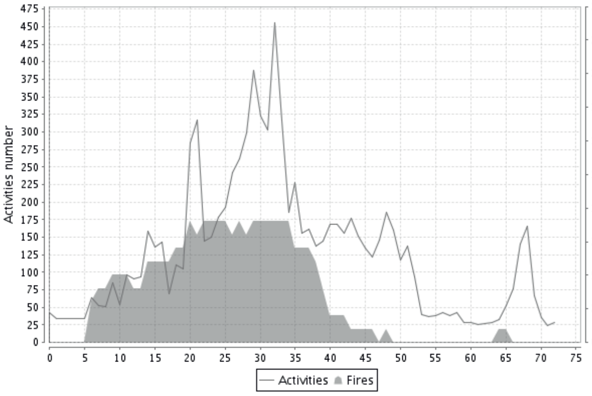


Figure 7. Factual agents activities in a fire scenario

V. CONCLUSIONS

We have proposed in this paper a part of an agent-based system that intends to help emergency managers to detect risks and to manage crisis situations. The main goal of our approach is to create a system that must be independent of the subject of study and that must be able to adapt its behaviour autonomously according to the environment change. We have described here an original idea, using an agents organisation, that allows the system to perceive occurred facts and to create its own representation of the situation. The final aim of the system is to recognize situations and to inform users about their potential consequences. We have demonstrated the ability of the factual agents to react and to change their behaviours according to the sensed hazard. Our current work concerns the creation of the factual agents clusters, using the assessment agents, and the way they will be stored and managed in the base. Therefore, a rigorous formalisation of clusters as well as distances measures to allow their comparison should be set up.

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