An Agent-based Approach to Envision the Future

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ABSTRACT

The need to envision the future is not new; it has existed since the beginning of human-kind. What it is new is the applicable technology that is available in a specific period of time. It is vital to research in the field of methods, techniques and tools that allow us to foresee the future. Although this problem is common to any area, an urgent solution is required to those with critical social repercussions.
It is not usual to find a critical social system which evolves according to predictable guidelines or tendencies. This paper presents a solution to model the opinions of an experts group with the aim of predicting possible future scenarios.
This paper includes the description of a specific process to elaborate the information elicited from the experts by using fuzzy logic and the development of multi-agent systems (MAS) to automate the creation of such scenarios.

Keywords

AI (Artificial Intelligence), MAS (Multi-Agent Systems), foresight, prevention, prospective, crisis, scenarios.

INTRODUCTION

This paper presents a solution to model human experts' opinions with the aim of generating future and possible scenarios. Although the problem of foreseeing the future is common to any area, an urgent solution is required to those with critical social repercussions. Fields like national security, demography or economy are examples of areas in which Prospective techniques are applicable.
Before facing a future scenario, the first and fundamental phase is to foresee it. It is better to be prepared for future scenarios rather than suffer their consequences. After figuring out the possible future scenario of crisis, we should analyze all elements or factors which should be modified in order to foster or hinder the scenario to materialize.

This paper gives a general view about the ways to foresee the future, introduces a MAS oriented solution and finally applies the new approach to a real case study.

The goal of our current research is to obtain an applicable technology which enables us to be aware of possible critical scenarios before they actually materialize, allowing us to analyze them and come up with appropriate risk mitigation strategies. The project includes the application of a specific methodology (Castillo, 2009) to foresee possible future scenarios of crisis based on the opinion of human experts and the development of multi-agent systems (MAS) (Riecken, 1994) to automate the creation of such scenarios.

Getting results in this field will enable the achievement of a new technology, and also a suitable methodology for the development of automated environments for the prevention of scenarios of crisis.

WAYS TO FORESEE THE FUTURE

The necessity to foresee the future is not new. Man has always felt the necessity to predict what is going to happen. We can gather the different methods to foresee the future in four main groups: Supernatural,

Reviewing Statement: This full paper has been fully double-blind peer reviewed for clarity, relevance, significance, validity and originality.

Hermeneutics, Technical and Anticipatory.

Future facts or situations known by revelation, prophecy or even astrology can be included as a supernatural way to foresee the future. Unfortunately, this group does not include serious and trustable procedures, so it is not advisable to rely on such techniques.

Hermeneutics is related to social interactions oriented to discuss the future. Opinions, utopian situations and even science fiction can be included in this group.

Within the Technical group we can find mathematical models that are developed to extrapolate past and present data in order to predict future results. The study of tendencies permits us to approximate future situations in stable dynamic systems. Econometrics, demography and meteorology are sciences that can be included in this group.

Unfortunately, social systems don't always behave in a stable way; normally they evolve in an unstable or chaotic way. Furthermore, when a situation includes a great deal of different and heterogeneous variables, technical prediction becomes complex and unaffordable.

Anticipatory techniques try to avoid the problem of using technical prediction in unstable systems by using the opinion of a group of human experts. The expert's opinion embodies relations among events or variables based on his/her personal experience; so complex relationships among heterogeneous events are mentally treated as a whole.

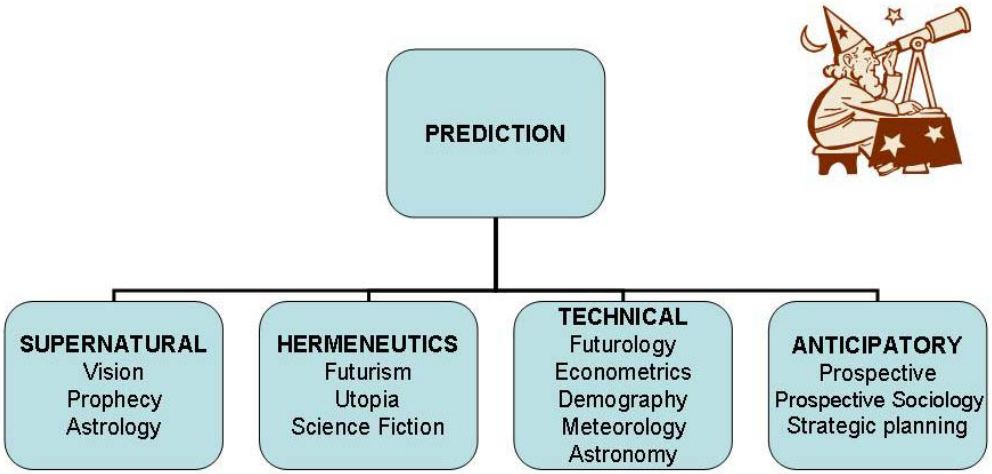

Figure 1. Ways to foresee the future

Technical prediction techniques are efficient in the creation of future scenarios based on stable dynamic systems in which tendencies of historical data are applied. However, inside the field of security it is hard to meet a stable dynamic system which generates scenarios based on predictable guidelines. The collapse of transports, economic crisis, natural disasters and terrorist attacks are just a few of many examples of scenarios of crisis which are difficult to estimate with techniques based upon technical prediction. Normally, the scenarios of crisis are created due to an accumulation of events that would otherwise be ineffective in isolation; however when occurring together they create an unsustainable and critical scenario.

In our every day lives there are many events, from domestic economy, incidence of criminality, social integration, to radical terrorist attacks. All these events belong to a specific scenario in which we are involved. We can study the future as the development of past and present events through the time.

From a conceptual point of view, our research is going to be developed under Prospective proceedings (instead of technical prediction). The final aim is to develop a technology which is able to identify and alert us to the generation of possible social scenarios of risk or crisis.

PROSPECTIVE. THE CLASSICAL APPROACH

Nowadays, the current use of Prospective is more related to the field of social sciences, although there are many other technical applications (Martin, 1995; Cuhls, 2003). Prospective tries to create an image of the future, reducing the consideration of the past, but never actually forgetting it. The prospective methods which correspond to an imaginative and intuitive exploration of the future lie on structural premises based on the past

but open constantly to changes (Godet, 1993). The opinion of groups of experts is used for the creation of future scenarios. The classical prospective method consists of (Bas, 1999):

- Submission of a questionnaire to the experts group to grade the probability of each event.
- Achievement of the common criterion of the group by using the Delphi method.
- Use of the cross impact technique to modify the conditional probability of each event.
- Elaboration of the cross impact technique to obtain the most probable scenarios.
- Analysis and interpretation of the most probable scenarios.

Initially, a group of analysts select the area of study and identify a list of possible events related to a future scenario.

After studying the events that are linked to a scenario, a human experts group has to grade the influence each event has on the others. This enables a more thorough study in terms of probabilities. The Delphi method (Dalkey, 1975; Turoff, 2009) is used to bring the group to a common conclusion. Hence, we are referring to conditional probabilities the Bayes theorem has to be taken into account and the isolated probabilities for each event have to be adjusted. After weighing probabilities, analysts have to produce a set of scenarios with their consequent probabilities. Those scenarios with higher probability will be chosen for a detailed sensitive analysis.

We can follow a similar process in analysing different contexts, like those related to banking, commerce, military operations, industry, disruptive technologies, security, etc. After the application of the method we obtain a matrix with future scenarios graded by their probabilities. The following figure shows an example of a matrix with ten possible scenarios. In the first column the events that can be involved in the scenario are listed. In the bottom line the probability for such scenarios to happen is given to illustrate a hypothetical example.

Ev	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10		
1												
2												
3												
4												
5												
6												
7												
8												
Prob	0.067	0.032	0.020	0.027	0.027	0.025	0.022	0.022	0.021	0.014	Σ ScN=	1.00

Cells in grey: the event doesn't exit

Table 1. Example of a matrix with probable scenarios

A MAS ORIENTED SOLUTION

In this section, we illustrate a new approach for prospecting the future based on a Multi-Agent System. The objective consists of the construction of a model that faces the problem of modelling future scenarios from a different perspective from the classical statistical prospective methods. We use possibilities graded by linguistic tags instead of probabilities, we take a different track towards the problem compared to classical methods.

We have followed the MECIMPLAN (Castillo, 2009) methodology to construct a software prototype that help us obtain results. This methodology describes the different steps and procedures to construct a MAS-oriented software prototype in this kind of domain. Nevertheless, MECIMPLAN can be used to develop intelligent systems, in both (Castillo, 2006) strategic or tactical planning.

Methodology steps

A methodology (Castillo, 2009) that permits us to solve a wide range of planning problems (Castillo, 2006) is used in this section. In general, we can assume that the way in which we apply the method depends on a

thorough analysis of the results obtained at each step. In certain circumstances, it is necessary to go back to previous states if the desired results are not obtained at a specific step.

To clarify the development of the software that supports our research we illustrate two specific phases of the methodology: Selection of agents and Model building.

Selection of Agents

We have used a neuro-fuzzy network (Haykin, 1999; Zadeh, 1975) aimed at reproducing human knowledge and experience in order to create a scenario by studying the influence among events. Thus, we talk about possibilities instead of probabilities and avoid using complex probabilistic techniques which are in most cases unclear for the human experts group.

We have implemented an intelligent search to make the sensitive analysis of variables (events) that can help us to arrive at an ideal scenario.

Model Building

We have built two agents in the MAS-oriented model: the Classifier agent and the Analyser agent. *The first one* will obtain the scenario after analyzing the proposed events. Each agent of the MAS has been developed to carry out a specific function; all of them are based on Artificial Intelligence procedures (Nilsson, 1998; Russell, 2003).

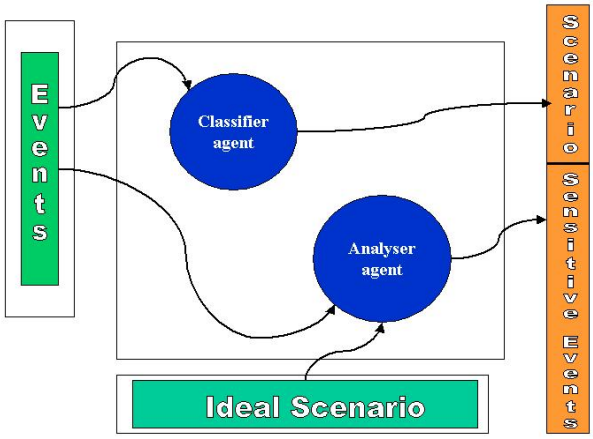

Figure 2. Conceptual Model

The knowledge extracted from the experts group will be used to train the Classifier Agent. Once the Classifier Agent has been trained, it can be used to generate new scenarios by presenting it with a set of events never used in the training phase. Thus, the knowledge of the experts group has been transferred to the Multi-agent System (MAS). It has been necessary to develop the classifier agent by means of fuzzy logic, since most of the times we express data in terms of adjectives. It is very common to define the relevance of the events or objectives in terms of linguistic tags. In this environment, Fuzzy Logic (Sugeno, 1985) provides a set of powerful tools.

The *second agent* is useful in determining which events can be influenced by us in order to arrive to the desired scenario. It is possible that the scenario doesn't match our expectations. In this case, the Analyser Agent is responsible for looking for the events which are to be influenced in order to get closer to an ideal scenario. We have used intelligent search as an Artificial Intelligence procedure to construct the Analyser Agent.

In Figure 3, we can observe the inputs to the model, the Agents we have designed to build the model, and the results we can obtain after its use. The model can be used for two purposes: to obtain a scenario as a result of the events, or to present an ideal scenario and look for the events that we have to influence in order to obtain or hinder such scenario.

In summary, the Classifier Agent receives the events and yields a scenario, while the Analyser Agent receives an ideal scenario and the original set of events and provides the list of events to be modified in order to obtain the ideal scenario.

WORKING WITH EXPERTS

One of the key points of the process is to establish the method to elicit the information from each member of the experts group.

In order to extract the information from the experts group and with the intention of developing a MAS as a new solution, we suggest to follow the following steps:

- To select the experts group. The number of experts depends on the problem and the level of expertise they have. Usually a number of experts between 10 and 15 is accepted (Dalkey, 1975). If they actually are experts, to add more members to the group would produce redundant information.
- To generate a set of questionnaires comprising the whole field of different future scenarios.
- The experts will answer the questionnaires by using specific adjectives from the natural language instead of probabilities.
- Most likely each expert will have a particular view about the proposed scenario. Consequently, there will be different opinions inside the group of experts. From a technical point of view, the aim is to elicit the information from each expert and to develop a knowledge module able to give a response about future scenarios like the group of experts as a whole.
- Analysis of the most possible future scenario produced by the MAS as a result of the information given by the group of experts.
- Study and identification of the events that have a major influence in creating the scenario.

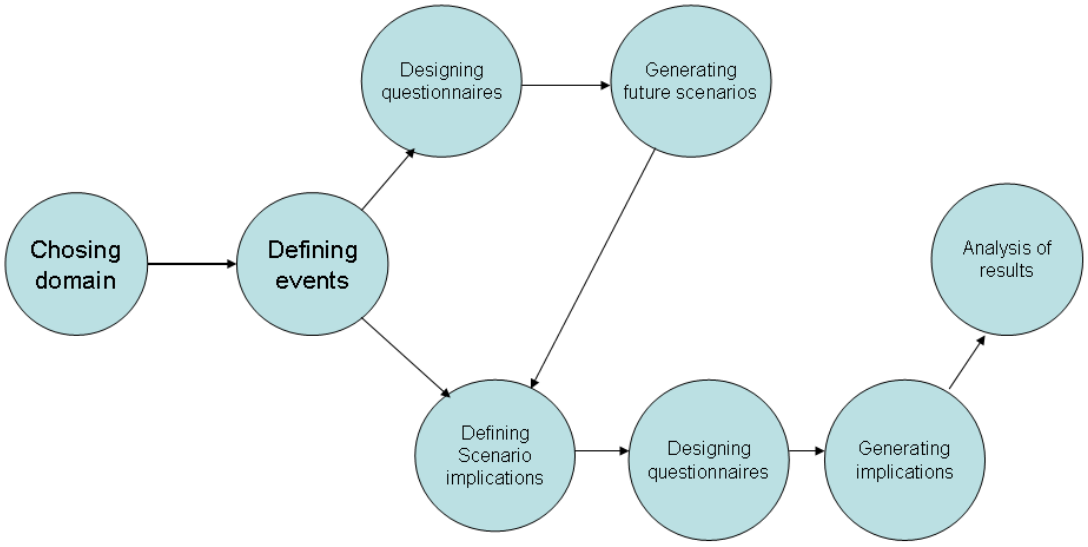

Figure 3. Map of processes

The above figure shows two branches. The upper branch describes the different processes that should be developed in order to generate future scenarios according to the opinions of a group of experts. In case we want to analyze the implications of the scenario generated in the upper branch or to study a specific scenario, we should proceed with the processes showed in the lower branch of the figure. We study the influence of external events not directly related to the scenario, on the possible scenario that is the objective of our study.

CASE STUDY: THE FUTURE OF THE COMMON POLICY OF SECURITY AND DEFENSE IN EUROPE

In this section we present a work that has been recently developed by the Spanish Institute of Strategic Studies and Tecnalia (Tecnology Corporation).

The objective of this exercise of prospective is to foresee the future of the Common Policy and Defense in Security (CSDP) under the horizon of the year 2020.

Defining the domain

A group of analysts from the Spanish Institute of Strategic Studies chose the domain in which we should develop a prospective study. In this particular case, the objective consists of envisioning the future of the European Policy of Security and Defense in the year 2020.

Defining events

The same group of analysts with the assistance of a group of technical experts from Tecnalia defined the general events that are related to the domain. We chose the list of events paying special attention to their independence among them. A number of seven events were identified and are listed below:

Event 1: The public opinions of the member states press their governments for a major development of the CSDP.

Event 2: the structures are rationalized to promote the planning and execution of the missions of the CSDP, with an integrated employment of the civil and military capacities.

Event 3: a change takes place in the architecture of euro Atlantic security as a consequence of a redefinition of the roles of the NATO and EU, and a change in the position of key actors as the USA and Russia.

Event 4: The ECSP (European Common Security Policy) develops a coherent form in accordance with the instruments foreseen in the Lisbon Treaty.

Event 5: The European Council decides for unanimity to implement a common European defense, in the terms established in article 27.2 of the Lisbon Treaty.

Event 6: The Capabilities Headline Goals (military and civilian), which are established by the EU to substitute those of 2010, are accomplished.

Event 7: The EC constitutes a number of forces adequately trained and equipped, and ready to be used flexibly in crisis management.

Designing questionnaires

Once the domain and the events were defined, Tecnalia designed the questionnaires to be answered by the experts group. The number of questionnaires cannot be numerous and have to represent the whole range of possible scenarios.

The group of experts was chosen by the Institute of Strategic Studies. Fourteen experts on international policy were selected.

In order to facilitate the knowledge extraction process a website was developed for the experts to answer the questionnaires on-line (www.escenariosprospectiva.info).

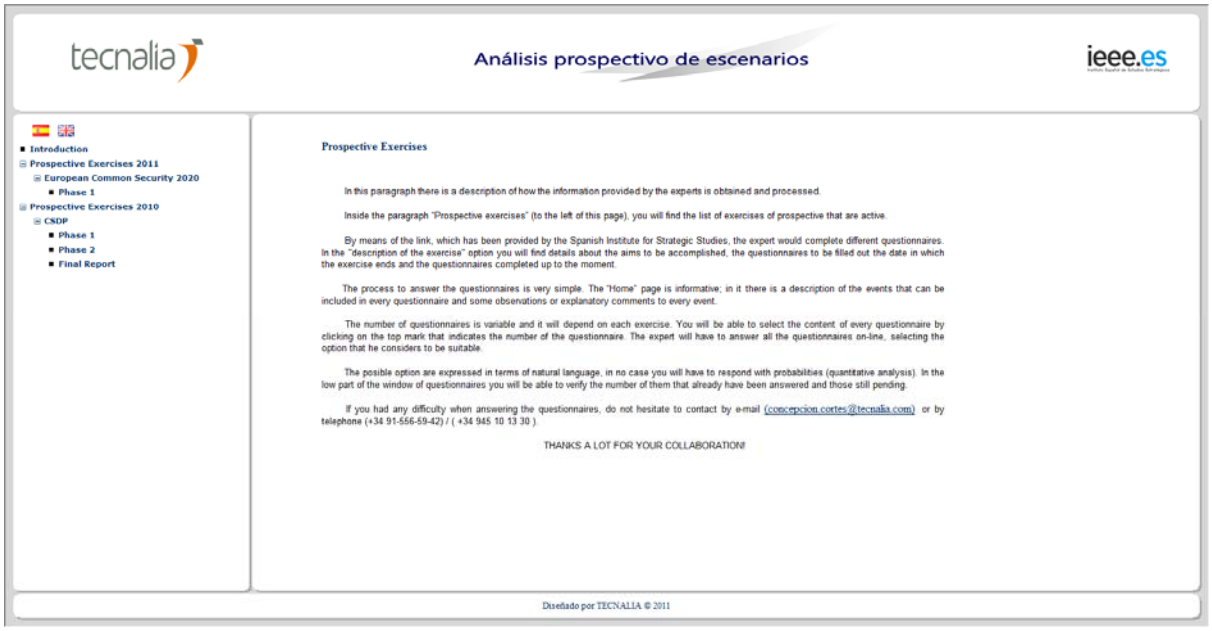

Figure 4. Website of the prospective exercise

The number of events identified by the group of analysts is seven. Consequently, the number of possible scenarios is 128. This number is the result of the different combinations of the events (2^7). From the 128 possible scenarios a number of fifteen has been selected as the most representative of them. Each expert has to express his opinion about the existence of each scenario in terms of possibility as 'very high', 'high', 'medium', 'low' and

'very low'. The following figure shows the experts' answers to each questionnaire. Each column contains the number of responses with regard to their qualification.

Very High	0	1	0	2	2	1	0	0	0	0	1	1	1	0	2
High	0	1	1	4	1	2	1	5	3	0	1	1	1	3	3
Medium	0	2	1	8	8	5	2	5	7	3	2	3	2	9	6
Low	2	6	5	0	3	5	4	4	3	1	5	4	4	2	3
Very Low	12	4	7	0	0	1	7	0	1	10	5	5	6	0	0
Total	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

Table 2. Experts' response

It is important to highlight that most of the answers follow a Gaussian distribution around a central value.

Generating future scenarios

The objective of this process is to treat the information in a logical and formal way. We are going to translate the results of all questionnaires into logical rules. Fifteen questionnaires with five possible answers produce seventy five possible rules. However, not all the possible rules have been chosen by the experts, only fifty nine out of seventy five possible answers have been selected by the experts. These fifty nine rules have been indentified as the main elements to be treated as part of the multi-agent system. Namely, these fifty nine rules will be the core of the classifier agent.

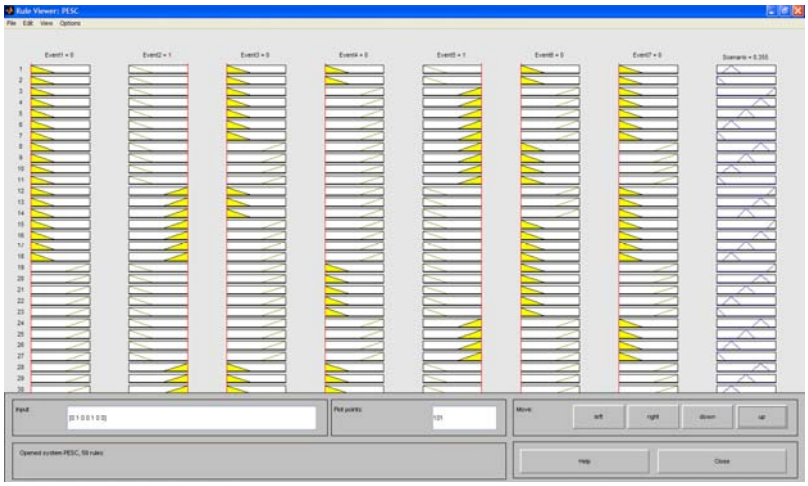

Figure 5. Rules generated by the experts

In order to treat all these rules, a fuzzy inference module has been developed. The following table shows the quantitative results for each questionnaire. In the table the column 'VALUE' expresses the result of the fuzzy module for each questionnaire.

	EV1	EV2	EV3	EV4	EV5	EV6	EV7	VALUE	POSSIBILITY
Q1	0	0	0	0	0	0	0	0.115	Very low
Q2	0	0	0	1	1	1	0	0.337	Low
Q3	0	0	1	1	1	0	1	0.266	Low
Q4	0	1	0	1	0	1	0	0.605	Medium
Q5	0	1	1	1	0	0	0	0.498	Medium
Q6	1	0	1	0	0	0	1	0.443	Medium
Q7	1	0	1	1	1	1	0	0.289	Low
Q8	1	1	0	0	0	1	1	0.519	Medium
Q9	1	1	1	0	0	0	0	0.486	Medium
Q10	1	1	1	1	1	1	1	0.227	Low
Q11	0	0	0	0	1	1	1	0.335	Low
Q12	0	1	0	0	1	0	0	0.355	Low
Q13	1	0	0	1	1	1	0	0.326	Low
Q14	1	1	0	1	0	1	0	0.515	Medium
Q15	0	1	1	0	0	0	1	0.530	Medium

Table 3. Fuzzy inference module results

As it is shown in the table, a scenario with no events (Q1) has a very low possibility of happening. Furthermore, a scenario in which the whole set of events (Q10) occurs has a low possibility of happening.

To extrapolate the fuzzy inference module results to the 128 possible questionnaires, a neural network is trained as part of the classifier agent. The neural network is trained with the data shown in Table 2. According to the conceptual model shown in figure 3, when introducing a set of events as input of the model we will get the possibility of producing this scenario as output. This output must be understood as the response given by the experts group as a whole for that specific input.

By using the software prototype, we have sought the scenarios with higher possibility of happening from the possible 128. We have obtained the following results:

- Scenarios with Very High possibility: NONE
- Scenarios with High possibility: 7
- Scenarios with Medium possibility: 57
- Scenarios with Low possibility: 56
- Scenarios with Very Low possibility: 8

	Ev1	Ev2	Ev3	Ev4	Ev5	Ev6	Ev7
Scenario #1							
Scenario #2							
Scenario #3							
Scenario #4							
Scenario #5							
Scenario #6							
Scenario #7							

Table 4. High-possibility scenarios

We can assume from the table of High-possibility scenarios that event 2 and 4 will be present at any of the most possible scenarios. Therefore, we can affirm that in the opinion of the experts group events 2 and 4 will be present in the temporal horizon of the year 2020. Namely,

- Event #2: The structures are rationalized to promote the planning and execution of the missions of the CSDP, with an integrated employment of the civil and military capacities.
- Event #4. The ECSP is developed coherently in accordance to the instruments foreseen in the Lisbon Treaty.

As described in figure 3, the upper part of the map of processes is completed.

PREVENTING CRISIS SCENARIOS IN SECURITY

The technology presented in this paper is applicable to any field; especially in those that prevention plays an important role. That is the case of security in which when preventing a crisis or undesired scenario is crucial to avoid negative or fatal repercussions.

By treating adequately the opinion of human experts groups, it is possible to envision critical or undesired scenarios in the field of security. For example, this technology could be applied to detect emerging scenarios of terrorism in which different social events are involved.

Combining this technology with others like pattern recognition, tracing human groups' behaviour or analysis of tendencies most of the prevention activities in the field of security would be covered.

We are available to collaborate with any research group or governmental institution to validate the result of this research work for preventing future scenarios in the field of security.

RELATED WORKS

The problem that we address consists of the construction of agent-based models to solve a specific operational problem such as foreseeing future undesired social scenarios. We tackle this problem with a methodological approach, with the aim of preventing undesired future scenarios from happening.

Consequently, the two main fields that are related to this paper are:

- Simulation with MAS-oriented architectures
- Prospective planning methods

The concept of agent generation is not new and has been addressed in many publications such as in (Much, 1999; Durfee, 2001). Agents have to be constructed under a specific objective. There are many papers related to methodologies in this field; however, most of them are targeted at obtaining efficient communication among agents as in (Aarsten, 1996; Agre, 1996; Bradshaw, 1996). This paper tackles the specific construction of MAS-oriented models to solve strategic planning problems in the field of security.
Prospective is a well-known technique based on statistical methods, as described in (Godet, 1993; Bas, 1999). In this work a new solution is given on the basis of a MAS-oriented architecture. The model is built by using a methodological approach (Castillo, 2006).

FUTURE WORKS

In order to validate the architecture and new approach shown in this paper, in 2010 we have developed some prospective studies together with the Spanish Institute of Strategic Studies. The initial scenario on which we have worked is:

- Future scenarios for the Policy of Security and Defence in the European Union

According to the lower branch in Figure 3; currently we are working on the analysis of the future scenario that has been generated. We are studying the influence of international events, non-related to the scenario, but with possibility of hindering or fostering the scenario. The result of this analysis will be published soon.
We are also planning to work on the following subjects:

- The strategic and political future of Afghanistan
- The future of the North Atlantic Treaty Organization

We are also preparing a large scale European Project under the FP7 (Framework Programme 7) to validate the concept of MAS-oriented architectures for prospecting in the field of security.

CONCLUSION

In this paper we have presented the idea of applying Prospective as a useful tool to envisage future and possible scenarios of crisis or risk. We have illustrated the processes to elicit information from a group of human experts to create future possible scenarios. A similar set of processes can be used to analyze the implication of possible scenarios in relation with other non-related scenarios.
One of the most important advantages that this work can offer is the possibility of foreseeing future scenarios with computer aided control based on a MAS-oriented architecture. The use of a technology that permits to avoid complex statistical methods, as well as the development of a software prototype that supports the analysis of scenarios facilitates the repetition of any prospective study if the scenario changes or new biased events show up unexpectedly in the follow-up process.

Furthermore, by comparing our work with classical methods, we found the following advantages:

- A natural use of linguistic tags instead of probability to define the possibility or intensity of events.
- The achievement of a common criterion of the experts group without using the Delphi method.
- The study of the future scenario implications through an analysis of the events that should be modified in order to obtain an ideal scenario.

Finally, we have illustrated the application of this technology with a real case study.

In the near future we are going to validate the application of this technology by:

- A follow-up process on the progression in the development of the CSDP in Europe.
- New prospective studies

ACKNOWLEDGMENTS

This project has been partially funded by the Spanish Ministry of Science and Innovation under grant PID-520100-2009-1, within the National plan of Scientific Research, Development and Technological Innovation (2008-2011); and partially supported through the project ‘AT’ (CONSOLIDER CSD2007-0022, INGENIO

2010) and 'OVAMAH' (TIN2009-13839-C03-02).
We are particularly grateful to the Institute of Strategic Studies of the Spanish Ministry of Defense. Without their support we would never have applied the research to a real case study.

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