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Abstract: The stakeholders' involvement in any decision making process is a key point in the Integrated Water Management (IWM). A successful watershed management process has to be participatory, allowing the stakeholders working together to set criteria for sustainable management, to identify priorities and constraints, to evaluate possible solutions, to recommend technologies and policies, and, finally, to monitor and evaluate any possible impact. For these reasons, any kind of support for handling a fair, rational and efficient debate and for achieving agreements and compromises is strongly desirable. In this contribution, a Community Decision Support System, capable to assist individuals and groups in representing and communicating their own perspectives, is proposed. Furthermore, the system can identify conflicts among stakeholders assuming a *multi-level* perspective. In this research work, the definition of "fuzzy semantic distance" between the judgments expressed by each stakeholder is used as a clustering method . The resulting clusters are, then, used for a cooperative solution of the problem.

Keywords: Community Decision-making; Negotiation Support System; Group Cognitive Mapping; Fuzzy Clustering.

1. INTRODUCTION

In water resources management domain, increasing interest is posed to the stakeholders' participation. In this perspective, mutual learning, conflict management, and iterative and adaptive decision-making process can play an important role as means to address complexity [Hjorsto, 2004]. To enhance public participation in water management it's fundamental to allow all possible stakeholders, both individuals and organizations, to participate in the decision process. Thus, conflicts analysis and resolution have to be carried out adopting a *multi-level* approach, firstly involving individuals. In our contribution a Community Decision Support System is proposed. Such a system is able to support discussion and collaboration, it helps participants to structure their problem, to learn about possible alternatives, their constraints and implications and supports them in the specification of their own preferences.

Thus, the participatory process has to embrace the problem structuring phase. Many efforts have been made to support problem structuring in complex situation. Among this approaches, the Soft OR [Hjorsto, 2004] seems particularly interesting to enhance public participation. In the public participation context, the Strategic Options Development and Analysis (SODA) methodology can aid to structure multiple conflicting aspects and set individual's views into context. The cognitive mapping is at the core of the method. A Cognitive Map can be defined as a map made up of concepts linked to form chains of action-oriented argumentation [Eden and Ackermann, 2004]. In our research work, Cognitive Maps are firstly used to capture parts of individual stakeholder's point of view.

To identify conflicts in a multi-level perspective and facilitate the negotiation and the definition of the community's perspective of the problem and preferences, the system can support in creating the, so called, "communities of interests", which gather all the stakeholders having similar needs. Thus, a clustering procedure able to create clusters among the stakeholders' interests is proposed. Such a methodology is based on the definition of a fuzzy semantic similarity measure that has to be applied to the individuals' cognitive maps considering the opinions expressed by each stakeholder on the critical aspects of the problem.

This contribution is organized as follows: in the second section some aspects concerning the participation and the conflicts arising in water management are described; the third section is devoted to the description of the system's performances and architecture; in the fourth section a case study is presented.

2. ENVIRONMENTAL RESOURCES MANAGEMENT AND NEGOTIATION PROCESS

The awareness of the importance of shared decision process in complex domains, like water management, derives from the importance of stakeholders' role in such processes: if they are not involved at all in any alternative constructions and evaluations, then the decision process outcomes could be controversial and the proposed solutions could generate strong opposition, making those solutions unfeasible. Moreover, stakeholders' influence in the decision process is not only determined by the single stakeholder's attributes but also by the way in which different stakeholders' groups interact forming interaction networks [Hare and Pahl-Wostl, 2002]. The role of the participatory process in water management is also established by the European Community Water Framework, which strongly encourages the active involvement of all the affected parties in the resource management [Pahl-Wostl, 2001].
Conflicts of interest over water resources can be greatly due to the variety in quality demands and the number of stakeholders, which are affected, in different ways, by decisions concerning the use of the resources. Thus, water management should involve processes in which stakeholders jointly *negotiate* how they will manage environmental resources [Johnson et al., 2001]. Support for handling a fair, rational and efficient debate and for achieving agreements and compromises is required.
The literature about the negotiation support in natural resources management seems waivering between two positions: on one hand many approaches propose a negotiation support system based on stakeholders' modelling techniques and agent based simulations. The model is, then, used by the agencies to structure the negotiation in a manner that is likely to facilitate an agreement. On the other hand, it focuses on the communication among stakeholders as a basis for consensual outcomes [Becu et al., 2003]. In such a case, the models are helpful in negotiation because they provide stakeholders with potential consequences of various choices involved [Barreteau et al., 2003].
Among the approaches aiming to simulate negotiation, the agent-based modelling seems really interesting. In fact, it permits the coupling of environmental and social systems, allowing to model disaggregated human decision making in environmental management [Hare and Deadman, 2004]. An agent is characterized by a set of rules that govern both the individual behaviour and the interactions with the other agents. To define these rules some approaches start from observation of human societies and try to extract regularities among behaviour [Pahl-Wostl and Ebenhoh, 2004; Pahl-Wostl, 2002].
In our work we move from the concept that the negotiation is a process of social interaction and communication. In this perspective, conflict identification plays an important role, providing a means of understanding stakeholders' interests. In our works a methodology for conflict identification based on a fuzzy similarity measure is proposed.

3. FUZZY COMMUNITY DECISION SUPPORT SYSTEM

If negotiation is mainly a communicative action, Water Community Decision Support System (WCDSS) has to facilitate the exchange of information concerning a particular problem in water management among different community members. Hence, a water community panel is provided. Such a panel allows the members to subject to other community members a particular water management problem. Thus, a community member, individual or organization, can define a problem that could be considered relevant for water community. To support this phase of community decision process, a "problem structuring support module" have been included in system architecture. In our research work, Cognitive Maps are used to capture parts of stakeholders' point of view. To help user in defining his/her own Cognitive Map, an user friendly interface has been designed. Such interface drives the user step by step during the map creation. The first phase is the "concept identification", that is, after giving a short definition of the problem, the system asks to the user to define the important concepts for that problem. The interface provides information on what "concepts" mean, how to define them, etc. At the end of this phase, the system shows to the user all the concepts in a graphical way and asks to him/her to identify possible links between the different concepts simply drawing an arrow. The user can define the link's strength choosing among three terms (weak, strong and very strong). After that, the cognitive map is shown to the user, which can change both concepts and links until he/she feels that the map actually represents the problem.
Thus, after the first step an individual's cognitive map is defined. The map is stored in the community panel and an user's problem description becomes available for other members of the community.
In this work, the cognitive maps analysis has been made using Decision Explorer (DE)

(www.banxia.com), a software package developed by the University of Strathclyde and largely adopted for map design and analysis. DE allows us to compute the *domain* and *centrality* of a concept, which provide information about its importance. More in detail, the domain measures the importance of the concepts by assessing their potency, i.e. the number of direct links (both as input and output). The centrality measures, instead, the importance by considering both direct and indirect links [Albino et al., 2002]. Thus, *key concepts* of user's map can be defined by using concepts with high degree of domain and centrality. To increase the user's confidence in system results, the key concepts are shown to the user that can suggest some changes. Moreover, the system asks to the user to group key concepts to create sets, that is, groups of concepts that deal with a specific issue or topic. The relevance of each set (i.e. the number of concepts per set and the importance of contained concepts) is a further measure of the importance that different issues have for different individuals. The user assigns a name or label to any different sets.

When other community members log on to the system, a community panel module provide them information about the problems already "annotated" on water community panel. If they are interested to these problems, the system supports them in constructing *their own* problem definitions. They can also modify the already annotated cognitive maps , adding or deleting concepts, or changing the links. At the end of this stage, different problem definitions are stored in the system and all the information about the stakeholders' interests are known.

As stated before, conflicts in environmental resources management can emerge at different level. In this work a first phase of conflict identification and resolution is performed using individuals' cognitive maps, but the concept of "community of interests" has been also considered. These communities could be defined as groups of people that share similar interests. To create these communities, the proposed system uses the sets of key concepts contained in all individual's maps. To define the communities, the following formula has been adopted:

$$S(x,y) = \frac{\sum_i w_x(i) \cdot C_x(i) \cdot C_y(i) + \sum_i w_y(i) \cdot C_x(i) \cdot C_y(i)}{\sum_i w_x(i) + \sum_i w_y(i)} \qquad (1)$$

where: $w_x(i)$ is the relevance of *i*-th sets f concepts according to the opinion of stakeholder *x*; $w_y(i)$ is the relevance of *i*-th sets f concepts according to the opinion of stakeholder *y*; $C_x(i)$ is equal to 1 if the stakeholder *x* considers sets *i* or it is equal to 0 if not; $C_y(i)$ is equal to 1 if the stakeholder *y* considers sets *i*, or it is equal to 0 if not. The value of *S(x,y)* is in the range [0,1].

Therefore, the interests of the stakeholders *x* and *y* are similar if *S(x,y)* assumes a high value, that is, both if cognitive maps have many common sets and relevance of common sets is high. In the following figure, the membership function to the set "Similar" is shown.

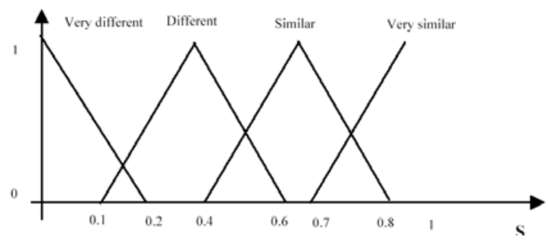

Figure 1. Fuzzy Semantic Similarity Measure

The negotiation within each community allows us to define the "aggregated" cognitive maps (e.g. "environmentalist cognitive map"). Referring to the agent-based modeling of negotiation process (see section 2), these aggregated maps could be compared to the "average" behavior of the "typical" agent. In our approach, the average behavior is defined by a negotiation process among individual stakeholders.

In a community decision process, the alternatives are not defined *a priori*, rather they emerge during the process because of the interaction among participants. Thus, after the communities of interests have been defined, the stakeholders can negotiate to define alternatives with the members of the same community.

At the end of the first phase of negotiation, each community has its own proposed alternatives. At this point a second level of conflict has to be identified. During this phase new groups can be created considering the agreement among the communities. These groups can be called "coalitions". To create these coalitions, the communities' opinions about alternative have been used. In this phase, the fuzzy set theory has been adopted since stakeholders' opinions are expressed in linguistic terms (e.g., very good, good, moderate, etc). To define the possibility of creating coalitions among the different communities of interests, the following fuzzy semantic distance has been used [Munda, 1995]:

$$S_d\,(A, B) = \Sigma \mid \mu_A(x_i) - \mu_B(x_i) \mid$$

where, $S_d(A, B)$ defines the similarity degree between two fuzzy sets A and B. In our work, S_d represents the similarity between the opinions expressed by two different communities; $\mu_A(x_i)$ is the membership degree of i-th alternative to the fuzzy set "Good alternative" based on judgment expressed by community A and $\mu_B(x_i)$ concerns the judgment expressed by community B.

Considering the opinions of all communities of interests, the system creates an agreement matrix, highlighting the communities that can create a coalition, that is, communities with a high degree of similarity. A new fuzzy set called "Similar" have been created and the similarity between two communities can assume four different linguistic values (i.e.: very similar, similar, different and very different) according to the value of S_d.

After this stage, it becomes fundamental to start the negotiation process among coalitions, whose results are an improvement of the agreement on any management action.

The architecture of the proposed system is shown in Figure 2.

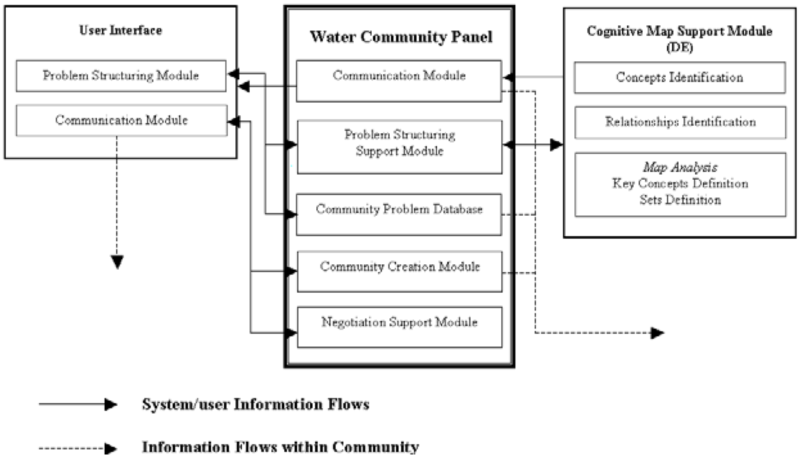

Figure 2. System Architecture

4. CONFLICTS NEGOTIATION IN WATER RESOURCES MANAGEMENT

Our research work deals with conflicts identification and resolution in water resources management in the Candelaro River basin, located in the north of the Apulia Region. The aim is to create a Negotiation Support System to be included as a module in a DSS architecture able to facilitate the integrated water resources management in this basin. In this perspective, we test our work applying the methodology for conflicts identification in a case study concerning the water management in scarcity condition. In this phase of the work, the user interface has not been yet developed. Thus, we built individuals' cognitive maps by interviewing different possible stakeholders.

More in detail, we interviewed the chief of the Local Water Management Agency and the users of the irrigation network (farmers) to define their cognitive maps. As described in the previous section, the degree of similarity among their interests has been identified. Following the proposed methodology, the first phase of problem structuring concerned the concepts identification. Thus, we supported the interviewees to identify concepts by explaining them what concepts mean in our methodology and providing them with some example. At the end of this phase, the interviewee was asked to define the links between the concepts and to define the strength of these links. In the cognitive map, we used different graphical representation for the links according to their strength. The cognitive map of the chief of the Local Water Management Agency is shown in figure 3.

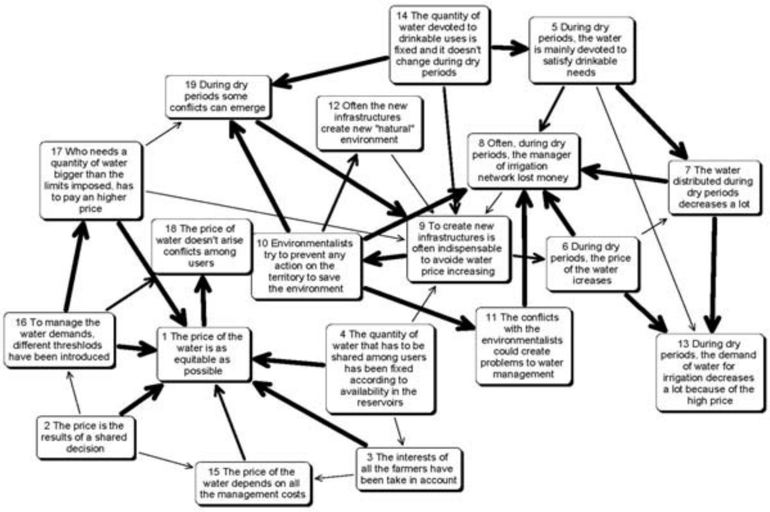

Figure 3. Local Water Manager's cognitive map.

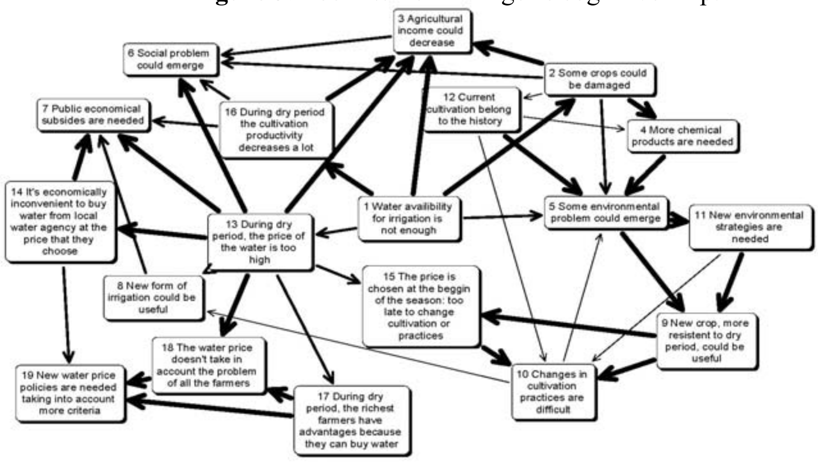

Figure 4. Irrigation network user's cognitive map

To define the *key concepts* of this map, we considere the concepts with a high number of links characterized by a high degree of strength. In the following, the key concepts of previous map are listed in a descending order of importance: 1) To create new infrastructures is often indispensable to avoid water price increasing; 2) The price of the water is as equitable as possible; 3) Often, during dry periods, the manager of irrigation network lost money; 4) Environmentalists try to prevent any action on the territory to save the environment; 5) During dry periods, the water is mainly devoted to satisfy drinkable needs; 6) During dry periods, the price of the water increases.

After this step, the interviewee was asked to group the concepts and to assign to each set a label. The sets identified by the chief of water agency are: 1) water price (very important); 2) infrastructure developing (important); 3) economic problem in scarcity condition (not important). Between parenthesis the relevance of each sets is reported. The relevance is defined considering the number and the importance of concepts included in each set.

We interviewed also an user of the irrigation network and, following the same methodology, we built his cognitive map (Figure 4). Grouping the concepts, three sets have been defined by the user: 1) water price (very important); 2) damages to the cultivation (very important); 3) strategies to safe the cultivation (important).

The degree of similarity between the interests expressed by the chief of local water agency and the irrigation network user can be calculated using the formula reported in section 3. According to this formula, the degree of similarity is: $S(x,y) = 0.43$. Therefore, using the membership function proposed in previous section, the interests expressed by the two stakeholders can be considered *similar*. In fact, both of them consider the "price of the water" as a very relevant issue during the dry period. Of course, they consider this issue from different point of view, but it could be considered as a point to start the negotiation process.

6. CONCLUSIONS AND FUTURE DEVELOPMENT

In this contribution a Community Decision Support System able to enhance the stakeholders participation in water resources management has been proposed. In the definition of such a system, we move from the idea that the community decision-making process is not only a "voting" process, in which the community members can only judge the different alternatives already defined by a central authority. On the contrary, from a community decision-making perspective, each member can highlight a problem relevant for the community and the alternatives have to be created in a collaborative environment. Therefore, the proposed system supports individuals to structure their problem perspective and to proposed it to the other community members. Since now, only the module for conflicts identification has been developed. To support negotiation among stakeholders, many other modules need to be defined and it is going to be done in order to complete the system architecture. Moreover, the future developments of our research have to deal with some disadvantages emerged in this first phase of the experience. Mainly the drawbacks are related to the human language ambiguity. In fact, as stated in the previous sections of this work, the definition of similarity measure for conflicts identification is based on the comparison among the labels assigned by each stakeholder to the set of concepts. Unfortunately, different users can assign different labels to similar sets. Therefore, important information could be lost and the results of conflicts identification phase could be wrong, misleading the negotiation process. During *vis-à-vis* interviews we overcame this drawback leading the problem structuring process. That is, when the two interviewees assigned the labels to their sets, we suggested some small changes to the labels if the sets were similar according to the contained concepts. Such an operation was easy in our experiment since the interviewees were only two. Thus, it was not difficult to analyse the sets and to suggest changes. On the other hand, the proposed system has to facilitate the negotiation within a whole community that could mean, perhaps, hundreds of cognitive maps. Hence, many other studies aiming to overcome this drawback using argument analysis, fuzzy set theory, Artificial Intelligence, etc., are needed.

Furthermore, the role of Internet as a tool for the democratisation of the decision-making process has to be investigated.

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