Collaborative Decision-making in Multi-agent Systems for GIS Application

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Abstract—**Group Decision Making (GDM) is an important human activity and it has many practical applications in society, economy, management and engineering, etc. Researchers are faced with new challenges in research on theory and methods of GDM with the rapid advent of internet and information technology. One of the challenges in collaborative work is social decision making in a computer mediated environment. Social trust models like recommender system, Bayesian trust for pervasive computing, are becoming invaluable part of distributed systems, where uncertainty prevails. In this paper we have proposed a Trust based collaborative decision making algorithm for distributed environment in which a group of agents collaborate for decision making.**

Keywords—**Collaborative Decision-Making (CDM), Multi-Agent System (MAS), Trust, Computer supported collaborative work (CSCW), Artificial Intelligence.**

I. INTRODUCTION

A powerful, extensible strategy for overcoming the bounds of intelligence present in any AI system is to put the system in a society of systems, so that it can draw on a diverse collection of expertise and capabilities in the same way that people overcome the limitations of individuals by coordinating in groups. Research in Distributed Artificial Intelligence (DAI) or Multi Agent Systems (MAS) [1] [4] concentrates on understanding the knowledge and reasoning techniques needed for intelligent co-ordination and evaluating this understanding in computer systems. Decision making in MAS [2] [5] is an important task that often involves choice from a discrete set of alternatives, for the purpose of attaining a goal. Distributed collaborative decision making is gaining importance among researchers due to its wide application range.

Distributed collaborative decision-making is a principal strategy for effective implementation of CSCW (Computer Supported collaborative Work) [3]. CSCW concentrate on applying communication and information technologies to the problem of supporting and enhancing group interaction and decision making activities. This kind of interaction is aided by a group decision system, which allows a set of individuals or experts to engage in a collaborative decision-making process in a CSCW. Since collaborative group decision-making has many practical backgrounds in economy, management, society and engineering, theory and methods of group decision system has been a very important research field in information technology. With the development of internet, electronic communication, knowledge based economy and information technologies, more attention in paid to Group Decision Making (GDM) [26] problems.

Geographic Information Systems (GIS) is one of the areas, where group decision making is an integral part. GIS and Decision Support Systems (DSS) [24] are mechanisms that can be used to provide managers with information needed to make sound resource management decisions. GIS problems are growing in importance as more and more people with concerns about environmental, land use, natural resource and transportation are involved in decision making. Many geographical decision problems are involving uncertainty in which information may be incomplete or not available. This situation makes decision making a complex task to the experts. Methodologies for group decision making include work on GIS extensions [27] [28] aimed at improving its decision support capabilities, leaving the uncertainty parts of the GIS problem for the decision maker's judgment. The decision makers need to arrive at consensus about the final decision through collaborative work.

Trust is a basic feature of social situations and plays a critical role in problem solving, organizational performance and organizational communication such as MAS applications and domain knowledge based GIS applications. Trust is one of the most valuable group components and is essential to the process of group influence and collaboration [9] and also, Trust models are becoming an integral part of distributed systems. Trust renders agents to enhance their collaboration significantly [10]. In order to effectively support group participation in decision making, social collaboration and decision analysis tools must be integrated. The existing frameworks [20] [21] [22] have emphasized technological issues of group support, and social issues such as relationship, roles and trusting behavior are not addressed. We have attempted to address this situation by developing a formal notion of trust that is present between individuals in collaborative environment. In this paper we have proposed a collaborative decision making algorithm for GIS Application.

The structure of the paper is as follows: section 2 covers relative work, problem definition is given in section 3; proposed collaborative decision algorithm is presented in section 4. Trust computation and GIS application is covered in Section 5 and section 6 concludes the paper.

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II. RELATIVE WORK

Decision making that involves uncertain data is challenging for human decision makers and highly complex problems are usually solved by a team of experts in organizations. Supporting group work, where team members may be in different locations and working at different time emphasize important aspects of communication and computer technologies. CSCW has evolved to provide effective support in group task. CSCW advanced tools include add-ins for analysis, surveys and modeling, which allows group to weight or rate alternatives against a list of criteria. Social Judgment Analysis [25], Nominal group technique [3] and Delphi [5] are some of the formal consensus development methods. There is a need to restructure these for distributed applications.

Spatial models are integrated in GIS and make it possible for GIS to complete some complex tasks as spatial decision support rather than merely spatial data management. As decision making is essential for any organization adopting GIS applications, researchers worked towards integration of decision models and expert systems. GIS-based spatial decision support system [20] [21] [22] [23] developed to study soil erosion.

The research work in MAS and decision making has addressed mainly computational issues, and social issues were given less interest. Recently due to advent of Knowledge engineering and information technology, research in E-commerce, online applications and pervasive computing applications [11] [17] [18] [19] are becoming popular and hence social issues such as trust, belief, empathy, and emotions are gaining importance. Trust is one of the most valuable group components and is essential to the process of influence and collaboration [12] [13] [14] [15] [16].

III. PROBLEM DEFINITION AND ASSUMPTIONS

CSCW systems have emphasized technological issues of group support at the expense of social issues such as roles, relationship and social trust protocol, which are common in organizations. Trust is a basic feature of social situations and plays a critical role in group problem solving, organizational performance and organizational communication. Trust is one of the most valuable group components and is essential in the process of collaboration. In order to make an improved decision in a collaborative decision making environment, trust based consensus method is essential for the team of experts. In order to address these issues, we are proposing a social decision-making algorithm and collaborative decision making framework for GIS as shown in figure 1, in which group of experts use trust as a social parameter. Hence, the objective is to make use of trust as a social parameter in decision making to improve quality of decisions.

Our ongoing experiment consists of two parts [27] [28]:
i) Collaborative agent architecture model- this will provide an interface for the decision makers to interact with other agents in the organization using communication network.
ii) Trust computation model- which provides inter-agent trust relation.

The following assumptions are made in the proposed algorithm.

- Collaborative decision process is a multistage process.
- The experts use the available decision models and their domain expertness, and give the decision or alternate selection for the task.
- Experts are presented with the task and decision model (Multi criteria decision-making mathematical model) and information processing aids.
- Each expert is allowed to discuss among other participants and clarify information regarding each decision using communication module.

IV. COLLABORATIVE DECISION MAKING ALGORITHM

There is a need for a collaborative decision making based on social interactions in a distributed environment for an organization. The existing frameworks [22] [23] [24] lack of social interactions (such as trust, cooperation), which is very essential for any organization for effective decision making. We have proposed a trust based decision making algorithm. Here**,** the collaborative decision process is a multistage process. The experts/agents use the available decision models and their domain expertness, gives the decision for the task. The individual decisions provided by the experts are to be evaluated and the final decision is to be selected in the group decision process. Each expert is allowed to discuss among other participants and clarify information regarding each decision.

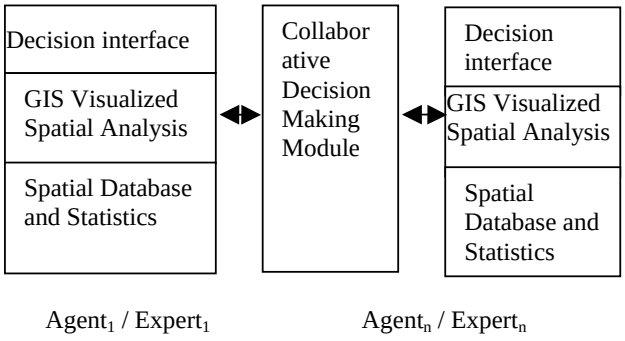

Fig.1 Collaborative Decision Making

In our previous work [28] we have proposed a working model on collaborative decision making architecture using MAS, which enables a team of experts (Agents) to receive information about the task and derive individual decisions about the task. As there are many different decisions, group members interact with each other and establish trust relation. This can be captured by trust computation model which aggregates the trust values. This trust value reflects the recommended trust, direct trust based on current decision, and domain expert trust. The highest trusted decision is selected as the outcome of group consensus.

We have proposed the following algorithm to achieve agreement about the final choice.
The collaborative process initiates with parallel algorithm for N agents.
For each agent $a_{i=}$ 1 to N.

1. Receive information about task and team.
2. Process the information and provide individual decisions.

Collaboration interaction process

1. Collect Decision maker's decisions
   $D = \{d_1, d_2, \ldots\ldots d_N\}$
2. Initiate collaboration, exchange information
3. Each agent discuss about each decision, criteria, conflict resolution
4. Update behavioral parameters such as direct expertness trust, recommenders trust, and trust on current decision.
5. Aggregate the trust values.
6. Decision with highest value of trust is selected as final solution.

V. TRUST COMPUTATION AND GIS APPLICATION

We have considered soil erosion application of GIS for our experiment. Assessment and inventory on soil erosion hazard are essential for formulation of effective soil conservation plans of a watershed for sustainable development. The following are the factors considered for soil erosion: rain erosiveness(A_1), soil erosiveness(A_2), terrain slope erosiveness(A_3) and land cover erosiveness(A_4).

Erosion Hazard Index(EHI) is computed using equation1 where W is the weight assigned for each parameter A by the expert.

$EHI = [W_1(A_1) + W_2(A_2) + \ldots + W_n(A_n)] / (W_1 + W_2 + \ldots W_n)$ ….. Eqn 1

Each expert will be giving preference to these parameters based on their domain expertness and range of values varies from expert to expert and also the importance order given for above parameters for assessment of soil erosion of given site. This forms individual decisions of team members as shown in table 1.

As there is need for single final decision, the team members have to collaborate exchange these decisions and interact for trust evolution. Each team member gives his recommendations about all the decisions and team members as shown in table 3 table 4. For simulation we have considered five agents.

Each team member maintains a trust data $t_{ij} = A \times A \rightarrow S$, where t_{ij} means how much agent a_i trust agent a_j based on the decision of a_j and S refers to the range of trust values. This is a numerical value which captures the uncertainty of trust more accurately rather than binary values [0,1] as in [16]. Here we have taken recommended trust (table 4), trust on current decision (table 3) and domain expertness trust (table 2). The overall trust for each decision is aggregated and highest scored decision is selected as the final solution as per equation 2.

Trust on Di = [trust on current decision]+
[recommended trust]+[domain xpertness trust] …..Eqn 2

Table 1. Individual decision by team members.

Decision by Expert	Weight selection for computing EHI			
	Rain Erosion	Soil Erosion	Land Cover Erosion	Terrain Slope Erosion
D1	3	2	3	2
D2	2	3	2	3
D3	3	2	2	3
D4	3	3	2	2
D5	2	2	3	3

Table 2. Domain expertness trust by other agents about agent a1.

Agent	Trust
a2	0.7
a3	0.6
a4	0.7
a5	0.8

Table 3. Trust based on current decision about agent a1's decision

Agent	Trust
a2	0.5
a3	0.6
a4	0.4
a5	0.3

Table 4. Recommended trust about other agents from agent a1.

Agent	Trust
a2	0.2
a3	0.5
a4	0.4
a5	0.6

VI. CONCLUSION

In this paper we have given the importance of trust in group decision making. As GIS applications are gaining the attention of many researchers due to its wide applicability in decision making, there is need for research in the area of integration of decision models into GIS. Existing GIS decision tools fail to provide a good decision for the problems which involve uncertainty. In such cases domain experts have to collaborate and arrive at a good decision. In such situations trust plays a vital role otherwise, experts may use Voting, Ranking and negotiation methods to solve uncertainty problems. These methods are purely computational, and do not involve any social parameter for decision making. Hence we have proposed a trust based technique for collaborative decision which gives improved decision.

REFERENCES

[1] Michael Wooldridge,*An Introduction to Multiagent Systems*. JohnWileyand Sons Ltd, 2002.

[2] Michael Wooldridge, *Reasoning about Rational Agents*. MIT Press, 2000.

[3] *Multiagent Systems*, edited by Gerhard Weiss, MIT Press, 1999.

[4] V.S. Subrahmanian, Piero Bonatti, Jürgen Dix, Thomas Eiter, Sarit Kraus, Fatma Ozcan and Robert Ross, *Heterogenous Agents Sytems*, MIT Press, 2000.

[5] Stuart Russel and Peter Norvig, *Artificial Intelligence: A Modern Approach*, second edition, Prentice Hall, 2003.

[6] Rao, A. S., and George. M. P. 1991. Toward a Formal Theory of Deliberation and Its Role in the Formation of Intentions. Technical Report, Australian Artificial Intelligence Institute, Victoria, Australia.

[7] Sycara, K. 1991. Problem Restructuring in Negotiation. *Management Science* 37(10): 1248-1268.

[8] Sycara. K.; Decker, K.; and Zeng, D. 1998 Intelligent Agents in Portfolio anagement. In *Agent Technology Foundations, Applications, and Markets.* eds. M.Wooldridge and N. R. Jennings, 267-283. Berlin: Springer.

[9] Wooldridge. M., and Jennings, N. 1995. Intelligent Agents: Theory and pactice*Knowledge Engineering Review* 10(2): 115-152.

[10] Corkill, D. D., and Lesser, V. It. 1983. The Use of Metalevel Control for Coordination in a Distributed Problem- Solving Network. In *Proceedings of the Eight International Joint Conference on Artificial Intelligence (UCAI-83)*, 767-770.

[11] Carbone, M., Nielsen, M., Sassone, V.: A Formal Model for Trust in Dynamic Net- works. First International Conference on Software Engineering and Formal Methods (SEFM'03), Brisbane, Australia. September 22 – 27 (2003)

[12] McKnight, D. H. and Chervany, N. L.: The Meanings of Trust. Technical Report 94- 04, Carlson School of Management, University of Minnesota, 1996.

[13] Golbeck,J., arsia, B. and Hendler, J.:Trust networks on the semantic web. In Proceedings of Cooperative Intelligent Agents 2003, Helsinki, Finland, August (2003).

[14] Shadbolt, N. R.: A Matter of Trust. IEEE Intelligent Systems -(-):pp. 2-3. (2002)

[15] Grandison, T. and Sloman, M.: A survey of Trust in Internet Application , IEEE Communications Surveys Tutorials (Fourth Quarter), vol. 3 (4) (2000)

[16] Shi, J., Bochmann, G. and Adams, C.: A Trust Model with Statistical Foundation, Workshop on Formal Aspects in Security and Trust (FAST '04), Toulouse, France, Kluwer Academic Press, August 26-27, 2004 (to appear).

[17] A Abdul Rehaman and S Hailes Using Recommendations for managing Trust in distributed systems, In Proceedings of IEEE Malaysia ICC,Kaulalampur, November 1997

[18] M Corbone M Nielsen, V Sassone. A formal model for trust in dynamic networks. in Proceedings of IEEE ICSE,and FM , Brisbane, Australia, 2003

[19] D Quercia, L Capra S Hailes B-Trust Bayesian trust for pervasive computing, 4th international conference on Trust Management, Italy, May, 2006

[20] Jankowski, P. and Nyerges, T., (2001) 'GIS-Supported Collaborative Decision Making: Results of an Experiment, Annals *of the Association of American Geographers*, vol. 91, no. 1, pp 48-70

[21] Ron Strore, Jyrki Kangas. Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling. Landscape and Urban Planning, 2001, (55): 79~93

[22] Zhen Lie, Bryan C P, Alexandrids KT, and Jennifer J O. Distributed modeling architecture for MA based behavioral economic Landscape Model, Simulation: Transactions of the Society for Modeling and simulation International, 2005.

[23]Zongyao Sha and zifeng Hu. SSKM: Atool to improve spatial Decision Support ability of GIS,Proccedings of IC on GIS,2004

[24] Lou Yuanhua, Zhang F,Cheng X and Sun M. System framework of Edss based on Spatial Information fusion,IEEE,2004

[25] Hammond and Brehmer. Social judgement Theory,1979

[26] Yu Z C and Fan Z P . A framework of Group decision making in Network environment, International Journal of Computer Science and Network Security, Vol 6, No 4,April 2006

[27] Indiramma M Anadakumar K R " Trust based decision making in MAS for GIS applications ", IEEE conference proceedings RASIET2007, India.

[28] Indiramma M. and Ananda Kumar K.R. "Collaborative multi-agent system for decision making in distributed systems" , ICCCE08 , Kaulalampur , (communicated)