Integration Of Fuzzy Filtering, Case-Based Reasoning and Multiple Criteria Decision Techniques in Rescue Operations

Silvia Suárez, Beatriz López, Josep L. De La Rosa, Esteve del Acebo
Universitat de Girona
Av. Lluís Santaló s/n
17071 Girona, Spain
{sasuarez, blopez, peplluis}@eia.udg.es acebo@ima.udg.es
Tel: +34 972 41 84 78 - Fax: +34 972 41 80 98

Abstract.

In this paper we introduce a collaborative strategy approach in a multi-agent environment where case based reasoning, Multiple Criteria Decision techniques and fuzzy filters techniques are integrated. Case-based reasoning and Multiple Criteria Decision Techniques are in charge of decision making and fuzzy filter are responsible for agents listen message selection, taking into account the trust of emitter agents. This approach aimed at benefit agent coordination in the RoboCup Rescue Simulator environment.

1. Introduction.

Distributed environments are being a matter of study on the Artificial Intelligence (AI) community since 1970, more recently in what it is known as the sub-discipline of Multi-Agent Systems. The main goal of Multi-Agent Systems is to build interaction mechanisms that work as wells as humans interact [1]. Each agent has its own decision capabilities. Interaction occurs to achieve the agent goals either in a competitive or cooperative scenario.

A emblematical distributed problem is a disaster environment where rescue agents and victims interact. In this kind of scenarios, agent capabilities should be taken into account in decision making since they can be diminished. For instance, partial vision or listen capabilities can be reduced. Moreover, properties of trust and reliability for information exchange are important. It is not frequently that agents want to send false information to requested agents, but either untrustworthy or unreliable information can happens due to agent capabilities reduction.

In an attempt to provide agents with a robust decision making procedure in the rescue scenario, we have developed an approach in which CBR, Multiple criteria and fuzzy techniques have been integrated. On one hand, one well known technique for agent decision making is Case-based Reasoning (CBR). CBR has been proved useful in non-distributed domains [2] [3] and recently in distributed ones [4]. We propose to extend current models of CBR by including agent capabilities. On the other hand, we use fuzzy logic to build filters for information exchange. Our work is conceived round the RoboCupRescue simulator [5] where the information provided by every rescue agents is a critical issue and filtering mechanism become essential.

Our research is strongly related to the RoboCup Rescue simulator promoted by the RoboCup organization [5]. RoboCup is an international research and education initiative. Its goal is to foster Artificial Intelligence and Robotics research by providing a standard problem where a wide range of technologies can be examined and integrated [6] [7]. In the general project of RoboCup, Rescue is included with the aim to promote research and development in this socially significant domain, involving multi-agent team work coordination and physical robotic agents for search and rescue [5] [8].

This paper is organized as follows. First, the rescue scenario and agents were presented in 2. following in 3, the approach challenges are presented. In addition in 4, the agents cooperation in the rescue simulation is explained. The multiple criteria techniques applied at agent coordination is presented in 5. Then, local decision making through CBR is explained in section 6, and fuzzy filters to deal with the reliability of messages sent by other agents are described in section 7. We end by providing some conclusions.

2. Rescue Scenario.

The rescue scenario is a disaster environment caused by an earthquake. In this scenario one can find collapsed buildings, fires, and blocked highways, people under panic looking for safe places and rescue agents doing their work in order to help victims. The earthquake of Hanshim Awaji where more than 6500 citizens were dead, motive the research in this new disaster situation environment. The rescue agents frequently found blocked ways that difficult and even make impossible the location of victims. This is the reason of why the police agents should come to unblock this ways as soon as possible. The ambulance agents cannot rescue victims due to the fire. This is the job, which have to accomplish the fire brigade agents. In summary, this is a simulation environment where the rescue agents found several constrains, as in the earthquake real scenario.

The agents of RoboCup Rescue Simulator represent a human team and its control centrals. Fire brigade agents, police forces and ambulance team, compose the rescue agents. Centrals are conformed by the fire station, police quarter and ambulance centre. All agents have the same objective: to minimize the damage and rescue victims under a earthquake scenario.

The agent's performance is evaluated in RoboCup Rescue competition according to the follow expression:

$$V=(P + S/Sint) * sqrt(B/Bint) \qquad (1)$$

Where:

P: number of living agents,
S: remaing HP of all agents,
Sint: total HP of all agents at initial,
B: area of houses that are not burnt,
Bint: total area at initial.

As greater is V better is the performance of the rescue team. The disaster simulation system shows 300 minutes after the earthquake happens. A minute in the disaster space corresponds to a cycle in the simulation system.

2.1 Simulation system.

The simulation system consists of several disaster sub-simulators, the GIS (Geographical Information System), the viewer and the kernel. In addition, civilian agents are also regarded as a part of the simulation system in the competition. The simulation system is managed by the kernel. The kernel proceeds the simulation as follows.

1. The kernel sends individual sensory information to all the agents in the simulation world.
2. Agents submit their action command to the kernel individually.
3. The kernel sends agents' commands to all relevant disaster sub-simulators.
4. Sub-simulators submit updated states of the disaster space to the kernel.
5. The kernel sends updated states to the viewer.
6. The kernel advances the simulation clock in the disaster space.

The simulation system repeats this loop 300 times. Typically it takes few seconds to simulate one turn. All the agents must decide an action for few seconds.
For more details of the simulation system, refer to [9].

2.2 Agents in simulation scenario.

In the simulation environment there are two types of agents: rescue agents and victims. The rescue agents are subdivided as moving and fixed agents. The moving rescue agents correspond to fire brigade, police and ambulance. The fixed agents correspond to the agents that cannot move, for instance fire station, police quarter and ambulance centre. Its purpose is performing coordination activities to guide its teams.

When an earthquake happens, the civilian agents could die or be buried and hurt. Another moves to the neighbouring refuges in order to be safe. It provokes chaos and blocked ways, increasing the difficulty of the rescue agents.

In the actual RoboCupRescue Simulation League, there are initially 72 civilian agents, 5 ambulance team agents, 10 brigade agents, 10 police force agents, 1 ambulance centre agent, 1 fire station agent and 1 police office agent in the disaster space.

2.3 Abilities of agents

Every type of agent has some communication and acting capabilities, as presented in table 1:

Type	Capabilities
Civilian	Sense, Hear, Move, Say
Ambulance team	Sense, Hear, Move, Say, Tell, Rescue, Load, Unload
Fire brigade	Sense, Hear, Move, Say, Tell, Extinguish
Police Force	Sense, Hear, Move, Say, Tell, Clear
Agents centre	Hear, Say, Tell

Table 1: Agents capabilities

Furthermore, fire brigade agents have another properties as water quantity, which shows how much water is in the tank; and stretched length which shows how long the hose is pulled to the nearest [9].

Agents as ambulance centers, police office, and fire station can only establish communication to agents attached to them (i.e., of the same type), and with others centers. That is, the police office can receive and send messages to the police forces, the ambulance centers and the fire stations. However it cannot send messages neither to ambulances nor fire brigades.

According to real situations, agents have a limited scope. Agent brigades can see visual information in a radius of 10 meters. The visual information is related to collapsed building, victim's localization and so on. Center agents cannot perceive visual information. Agents can exchange messages by voice (say and listen) and communication services (tell and hear). In the former case, the message is perceived by others agents located into a circle of 10 meters radius. In the later case, the message is perceived by the agents of the same type than the sender and located into a circle of 30 meters radius. Center agents can communicate with other agent centers using basically communication devices.

One agent is capable to say or listen a maximum of 4 messages each simulation cycle, in which it should decide some action to perform. In this context, it is important to use a filter, in order to test the trust and reliability of every message send by other agents [10] and act consistently. Moreover, agent capabilities should be also taken into account and act or ask for help according to the information gathered.

3. Challenges

A disaster environment is a dynamic surrounding, where the situations are unpredictable. In order to minimize the earthquake damage, not only the rescue of victims is important, is at the same way important jobs related to fire extinguish and remove obstacles from the ways. Fire brigade and police agents perform this job, respectively.

The rescue agents have to accomplish their objectives under strong communication and surrounding perception constraints. Agents can only get visual sensory information within a radius of 10m in the large disaster space, which has an area of 500m × 500m. Furthermore, it is stringently limited for agents to communicate with each other.

4. Agent's cooperation

Rescue agents need to cooperate with other same type agents to reach the team objective. The fire brigade agents have to cooperate to the others to extinguish the spread fire due to the difficulty of this task for a single agent. In the same way, police single agents have to cooperate with another one.

In addition, the cooperation of different type agents is very important. The ambulance agents need fire brigade and police agents to accomplish their objective. The first one extinguishes fires and the second ones unblocks ways, doing possible the ambulance agent's job: look for victims.

Same and different type of agents need to communicate each other, but it is no easy due to communication constraints. Every agent only can send four messages each simulation cycle. More than four messages can cause disturb for message understanding. It is the reason of develops cooperation strategies taking into account this constrains.

5. Coordination: Centrals – Agents teams

Due to inter agent's communication restrictions, the centrals were used as coordination base for every agent team. The police quarter and the fire brigade station store the information sent by their teams. This information (related to the victims found) is sent to and saved in the ambulance central. Every ambulance agent sends to the central the information related to its availability and its own damage.

Taking into account this information, Multiple Criteria Decision techniques [11] are used by the ambulance centrals to determine which of it agents have to perform the rescue, under a specific situation. In this process, the importance of each constraint is evaluated. More details of this work using MCDM are presented in [12].

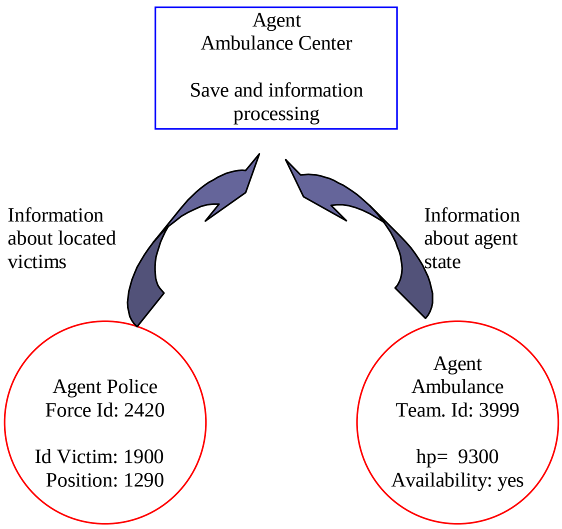

Figure 1. Information sent to centrals

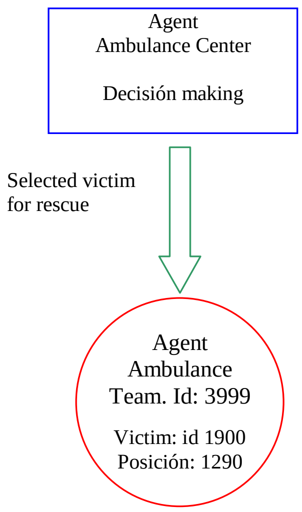

Figure 2. Decision making in the centrals

6. Case-based local reasoning

Case-based reasoning (CBR) is a methodology of problem solving in AI coupled to learning [13]. The learning facet of the methodology makes it especially suitable in dynamic environments in which agent behavior should be adapted to environmental changes. The task of CBR can be divided into four phases: Retrieve, Reuse, Revise and Retain. When a new problem arrives, similar cases are retrieved from memory. Then, the information and knowledge of retrieved cases are used to solve the problem. Finally, the proposed solution is revised and retained becoming likely to be useful for future problem solving[14].

Rescue agents use CBR to make local decision about their activity. Each case contains the following information:

- Goal of the agent, for example, to rescue victim 1900 (according to the information received from the central).
- Unsolved petitions: messages from other agents asking for help that are unattended, together with the trust value of the emitter agent.
- Agent physical capabilities, that vary through time:

  hp: Its a life indication. Initial value is 10000. The value is decreased by damage every step. Value ´0´ means dead.

  damage: The value of damage set when the civilian suffers from fire or building collapses. It goes From 0, when the agent is save on a refuge, to 200 in the case of building collapses.
- Context: information related to the agents scope, degree of buildings fired, distance to support teams, close to a victim, expected life time of the victim, etc. Most of this information is gathered by the visual capability of the agent and also by the information provided by other agents.
- Solution: action the agent has decided upon (including, leaving the current goal and attending other agent petition).
- Result: evaluation of the action performed (leading to success or failure).

Each team agent sends back the decision made on a simulator cycle (case) to its central; central agents gather team agent decisions (cases) and performs decisions regarding agent distribution round the rescue scenario.

Retrieval is based on the goal, unsolved petitions, agent capabilities and context components of the case base. Reuse consist then on transferring the solution. In the next simulation step, the result of the past experience (expected result) is compared against the current result. If the result differs from the expected one, the new case is retained.

7. Fuzzy logic Systems and Fuzzy Filters

Ambulance teams can require help from neighboring agents. However, due to the problem exposed above, agents should know the trust and reliability of all messages sent by their partners. For example, one agent can send help messages to their colleagues but their damaged situation does not guarantee that the help will arrive on time.

One way to get a trust value for each agent is by means of a fuzzy filter according to the work proposed in [15] (see figure 1). A fuzzy filter is defined as special case of the Mamdany fuzzy inference systems in which fuzzy rules have the following form:

$$if \quad A_1 \; is \; S_1 \; and ....and \; A_n \; is \; S_n \; and \; V \; is \; L_1 \; then \, W \; is \; L_2$$

Where:

- S_1, S_2, ...S_n are linguistic values, defined by fuzzy sets on universes of discourse X_1, X_2... X_n respectively.
- A_1, A_2... A_n are fuzzy variables taking values over the fuzzy power sets of. X_1, X_2... X_n.
- L_1, and L_2 are linguistic values, defined by fuzzy sets on the same universe of discourse U.
- V and W are fuzzy variables taking values over the fuzzy power set of U.

Thus, an example of basic fuzzy rule implementation in order to determine the message trust value sent by a fireman agent, taking into account its physical capabilities is:

If *vision* is *diminished* and *hp* is *> 5000* and *damage* is *< 80* then *trust* is *high*

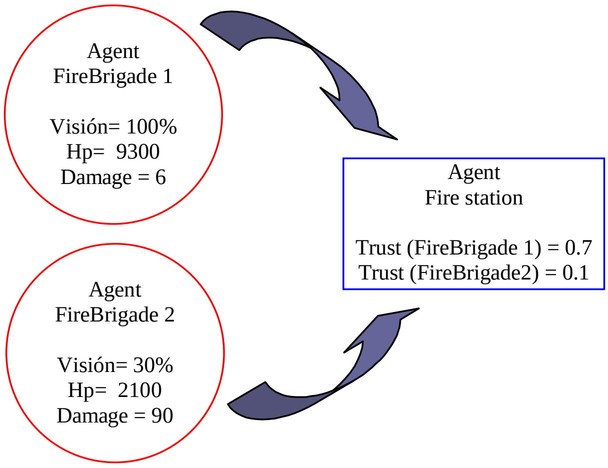

Figure 3. Trust filtering in according with agents capabilities

Then, each agent has fuzzy rules to compute the trust value of the agents in its neighbourhood. This trust value is a feature in which CBR retrieval relies in order to recover past experiences to decide next action (see previous section).

8. Preliminary results and future work

As a result of this research work, the ambulance team performance has been improved. According to the evaluation expression of RoboCup Rescue (1), the score V achieved is 38. The best score obtained in RoboCup Rescue 2002 is 90 by Arian; the second 87 by YowAI2002; the third one is 46 by NITRescue; and fourth is 34 by Kures2002; among 10 teams that participate in the 2002 tournament.

As future work, the developed rescue coordination strategy used in ambulance centre will be applied to the other central agents (police office and fire station). In addition, a cooperative strategy between heterogeneous agents teams will be developed. Using both, coordination and cooperative strategy to rescue operations (look for victims, fire extinguish and path unblock), we expect to improve the global performance of the rescue team in the disaster simulation area.

9. Conclusions

We have presented an strategy for the RoboCup Rescue simulation environment based on MCDM techniques, CBR and Fuzzy filters.

Our approach provide agents with the capability to filter messages to make decision making with the appropriate information. Filtering is based on fuzzy systems and decision making in CBR and Multiple Criteria Decision techniques. Benefit of the integration of these techniques is a more robust decision making process in an open environment. Further experiments will show the validity of the approach.

References

[1] Weiss Gerhard. Multiagent Systems: a modern approach to distributed artificial intelligence, MIT Press 1999.

[2] Ian Watson Applying Case-Based Reasoning. Techniques for Enterprise Systems. Morgan Kaufmann Publishers, Inc., 1997.

[3] Janeth Kolodner. Case-Based Reasoning. Morgan Kaufmann Publishers, Inc., 1993.

[4] Enric Plaza and Santiago Ontañon (2001), Ensemble Case-based Reasoning: Collaboration Policies for Multiagent Cooperative CBR. In Case-Based Reasoning. Research and Development: ICCBR 2001,. Lecture Notes in Artificial Intelligence 2080, p. 437-451. Springer-Verlag, 2001.

[5] http://www.r.cs.kobe-u.ac.jp/robocup-rescue/

[6] H. Kitano, S. Suzuki, J. Akita, RoboCup Jr.: RoboCup for Edutainment, Proc. of Int. Conf. On Robotics and Automation 2000, IEEE Press, NY, 2000.

[7] H. Kitano, M. Tambe, P. Stone, M. Veloso, S. Coradeschi, E. Osawa, H. Matsubara, I. Noda, M. Asada, The RoboCup Synthetic Agent Challenge 97.

[8] S. Tadakoro, H. Kitano, T. Takahashi, I. Noda, H. Matsubara, A. Shinjoh, T. Koto, I. Takeuchi, H. Takahashi, F. Matsuno, M. Hatayama, J. Nobe, S. Shimada. "The RoboCup-Rescue Project: A Robotic Approach to the Disaster Mitigation Problem". Proc. 2000 IEEE Int. Conf. on Robotics and Automation, April 2000 (ICRA2000).

[9] RoboCup-Rescue Simulator Manual-Versión 0 rev. 4

[10] Takeshi Morimoto, Kenji Kono, and Ikuo Takeuchi. The first Rescue Simulation League Champion

[11] R.R. Yager. On Ordered Weighed Averaging Aggregation Operators in Multi-criteria Decision Making. IEEE Transactions on SMC, volume 18, 1988.

[12] Silvia Suárez, Beatriz López, Josep L. de La Rosa. Co-operation strategies for strengthening civil agents' lives in the RoboCup-Rescue simulator scenario. Submitted to: RoboCup Rescue 2003, Padova, Italy.

[13] A. Aamodt, E. Plaza (1994); Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches. AI Communications. IOS Press, Vol. 7: 1, pp. 39-59.

[14] A framework of features selection for the case-based reasoning Wei-Chou Chen; Shian-Shyong Tseng; Jin-Huei Chen; Mon-Fong Jiang Systems, Man, and Cybernetics, 2000 IEEE International Conference on, Volume: 1 , 2000. Page(s): 1 -5 vol.1.

[15] Esteve del Acebo, Josep Lluis de la Rosa. A Fuzzy System Based Approach to Social Modeling in Multi-Agent Sistems (ID 118). Applied to AAMAS' 02, Bologne, Italy, 2002.