Geospatial Analysis of Cooperative Works on Asymmetric Information Environment

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Abstract. In the so-called Information-Explosion Era, astronomical amount of information is ubiquitously produced and digitally stored. It is getting more and more convenient for cooperative works in the sense of information sharing. Information aggregation systems are widely available and search engines are the most useful tools for finding resources on the internet. However, the use of information is not sufficient for cooperative works such as decision making. This is partly because, as the systems get larger, the stakeholders of the systems increase and they are on Asymmetric Information Environment (AIE). We do not share everything on the network. In this paper, we present the importance of AIE-oriented systems design for cooperative works using simulations and geospatial analysis on Multi-Agent Disaster Evacuation Model. As a result, using small data like positioning information and status information of agents, we can visualize the situations and take effective actions for cooperative works on AIE. Communication techniques on AIE such as signaling, positioning information monitoring and positioning information screening are effective for geospatial analysis of cooperative works on AIE. In conclusion, we can increase values from information flows by increasing effective actions for cooperative works using AIE-oriented systems design. Real field experiments are to be followed in our plan.

Keywords: Geospatial Analysis, CSCW, Collective Systems, Asymmetric Information Environment, Information flows, Multi-agent simulation

1 Introduction

In the so-called Information-Explosion Era[1], astronomical amount of information is ubiquitously produced and digitally stored. Not only human activities on the internet but also automated systems are producing digital data in the world. Sensor networks, video surveillance, system logs are working perpetually. Information flows create values in our society. Search engines are the best solutions that make information flows and create values on the internet. Sensor networks are valuable because they automatically measure specific data and make information flows. It is getting more and more convenient for cooperative works in the sense of information sharing.

Information aggregation and management systems like GIS (Geographic Information System) are widely available and search engines are the most useful tools for finding resources on the internet. However, the use of information is not sufficient for cooperative works such as decision making. This is partly because, as the systems get larger, the stakeholders of the systems increase and they are on Asymmetric Information Environment (AIE). We don't share everything on the network for collaboration. We don't need to share everything because the information needs are different from each other by roles and situations. We can't share the information sometimes due to network troubles at disasters.

In this paper, we present the importance of AIE-oriented systems design for cooperative works using simulations and geospatial analysis on Multi-Agent Disaster Evacuation Model. As a result, using small data like positioning information and status information of agents, we can visualize the situations and take effective actions for cooperative works on AIE. Communication techniques on AIE such as signaling, positioning information monitoring and positioning information screening are effective for geospatial analysis of cooperative works on AIE. In conclusion, we can increase the values from information flows by increasing effective actions for cooperative works using AIE-oriented systems design. Real field experiments are to be followed in our plan.

2 Related Works

In geospatial analysis and GIS field, systems are getting larger. Some countries are promoting NSDI (National Spatial Data Infrastructure [2]) concept to structure nation-level information aggregation systems. However, orchestrating multiple government sectors to share their information is a tough job because of AIE reasons. Current solutions for NSDI are sharing fundamental data and metadata [3] to search the contents efficiently.

Cooperative work has been studied as CSCW (Computer Supported Cooperative Work) field that is an interdisciplinary research area for social psychologists, sociologists, and computer scientists. CSCW concept is commonly defined by time-space matrix [4]. So geospatial analysis is well matched with CSCW concept. As the network infrastructures have been developed and systems are getting larger, the number of stakeholders tends to increase. AIE-oriented systems design is needed for a large-scale CSCW system like a Disaster Management and Support System [5]. In recent years, collective systems have gained considerable attention in large systems design with considering stakeholders as adaptive agents to establish coordinated systems from the bottom up [6].

Asymmetric Information has been studied in the field of contract theory in economics [7]. Information asymmetry is the situation that at least one party does have some information which the others do not upon transactions. There are two kinds of problems in this situation that are moral hazard and adverse selection. Moral hazard is the problem if information asymmetry happens after the contract. Adverse selection is the problem if information asymmetry exists before the contract. An example of moral hazard is employer's ignorance of the lack of employee's diligence after the employment. An example of adverse selection is employer's ignorance of the lack of employee's ability before the employment. It is known that monitoring technique is effective to cope with moral hazard problem and that signaling and screening techniques are effective against adverse selection problems. In this paper we tried to apply these techniques to systems design for multi-stakeholders' huge systems as AIE-oriented systems design. We enlarged the concept of asymmetric information to "Asymmetric Information Environment" because it is not only discussed on contract theory but also on communications theory.

3 AIE Example and Simulation Model

Information flows create values for society and AIE is the source of information flows. Because information flows stem from the information gaps on AIE as water flows from higher to lower places. The problem of AIE emerges where the stakeholders of the systems are not conscious of their differences on AIE and just promoting information sharing. The differences of information might make misunderstandings and sometimes ignoring the differences causes the problem.

3.1 Real-time Disaster Management and Support System

At first, we consider Real-time Disaster Management and Support System (R-DMSS: Fig.1) for example. R-DMSS is a network system that connects the emergency headquarters and the disaster sites. GIS is used by the central user for information aggregation and management. This system is supporting the cooperative works between emergency headquarters and disaster sites.

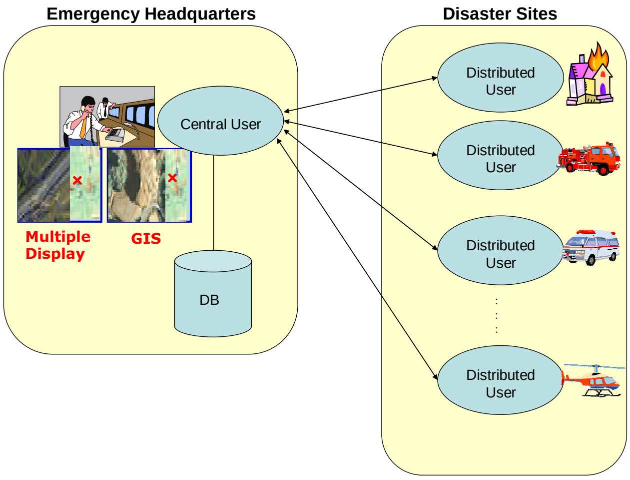

Fig. 1. Real-time Disaster Management and Support System

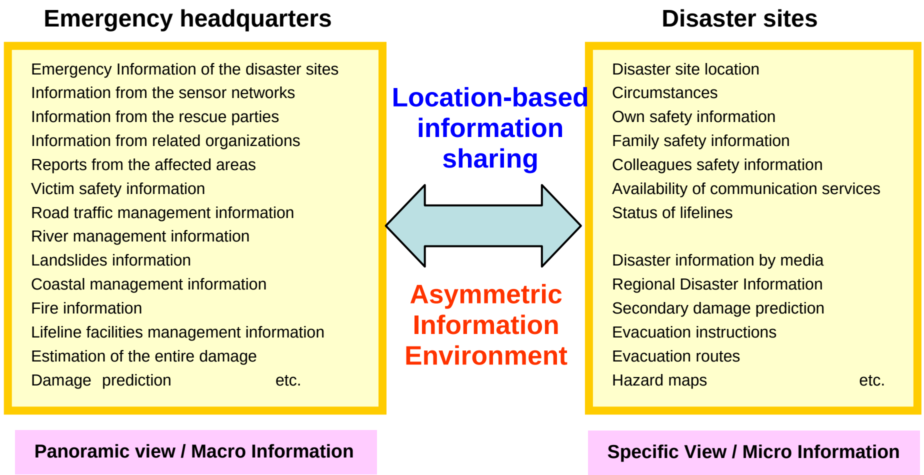

Fig. 2. Information gaps on Asymmetric Information Environment

As it is shown in Fig.2, location-based information sharing is useful on AIE, but information gaps inevitably exist. While cooperated works are conducted between emergency headquarters and disaster sites, the information they need are different from each other because of the differences of their roles and situations. Emergency headquarters need panoramic view and macro information. On the other hand, disaster sites need specific view and micro information. All the information are valuable only when they produce decisions for actions. We have to design the system so that information flows create values like immediate actions to rescue injured people.

3.2 Simulation Model

We analyzed the system on Multi-Agent Disaster Evacuation Model (Fig.3).

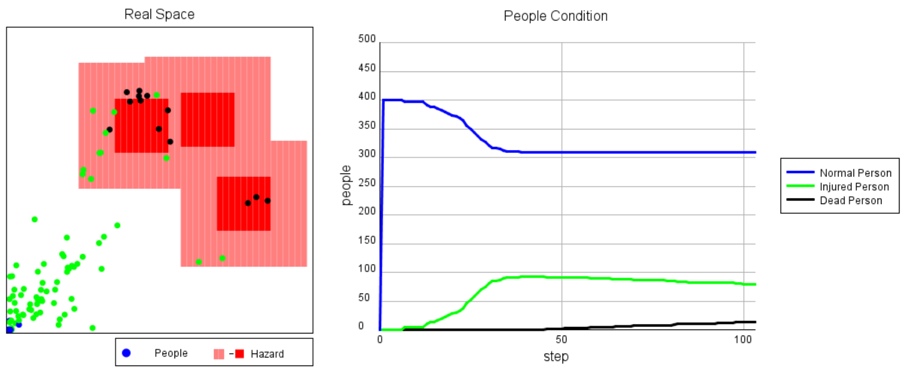

Fig. 3. Multi-Agent Disaster Evacuation Model

Table 1. Simulation Model Specification

Model Summary	People evacuate from the disaster site to the shelter on the simulation space.
Space	50×50 square area
People	100 to 500 people (specify the number from the control panel and randomly placed on the space)
Hazard	1-5 units (specify the number and randomly placed on the space) 8×8 square area: the core of the hazard 20×20 square area: the periphery of the hazard
Shelter	The shelter is at the lower left corner. People know it.
Rules	・To shelter people evacuated while damaged from the hazards ・the core of hazard affects people more than the peripheral ・According to the damage level, the condition of the people changes like normal (blue) → injured (green) → dead (black) ・People try to avoid the core of the hazard ・Movement of people is dwindling due to cumulative damage
Emergency Headquarters	track the location of people in some extent
Simulator	artisoc textbook, KOZO KEIKAKU ENGINEERING Inc.[8]

The specification of the simulation model is shown in Table 1. Using this model, we have already found the following [5].

- Using small data like positioning information and status information of agents, we can visualize the situations and take effective actions for cooperative work on Asymmetric Information Environment.

In this paper, we extended the model and investigated communication techniques on AIE by simulations. The simulation test methods were as follows.

Simulation 1.

(1) Emergency headquarters can track the location of people randomly, 10% at a step.
(2) Signaling technique Test: Injured person sends help alert when his damage level is increased. Individual differences for the decisions are randomly added.
(3) Positioning information monitoring technique Test: Emergency headquarters monitor the location of each person, compared to the previous location if he does not move any more. The motionless person detected is the target of rescue.

Simulation 2.

(1) Emergency headquarters can track the location of people who have the positioning terminals. The terminal penetration (TP) is the parameter of the simulation.
(2) Positioning information screening technique Test: Emergency headquarters identify rescue target area by screening of injured person’s trails from all the trails.
(3) To verify the efficacy of screening method, we counted the dead persons on the screened area for 10 times of simulations for each TP(10%, 20%, 25%, 50%, 75%).

4 Results and Discussions

The results of the simulations are as follows. We found that the tested communication techniques are effective on AIE.

4.1 Simulation 1

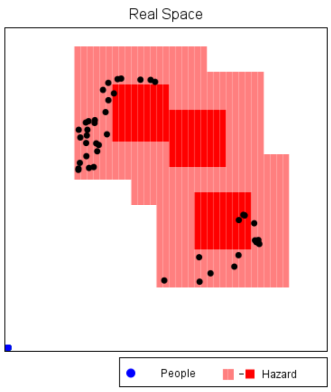

Fig. 4. Real Space View
(step 200, response 10%)

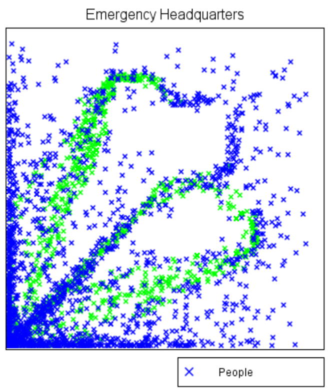

Fig. 5. Emergency Headquarters' View
(step 200, response 10%)

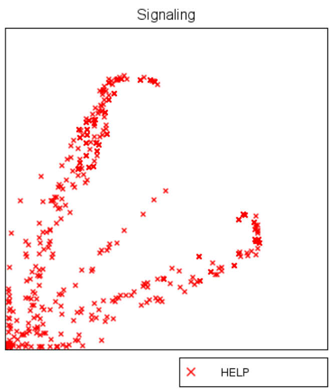

Fig. 6. Signaling
(step 200, response 10%)

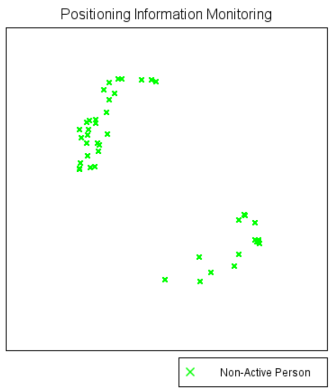

Fig. 7. Monitoring
(step 200, response 10%)

Spatial analysis. Comparing Fig.6 and Fig.7, signaling was more redundant than monitoring because the latter pointed out the same result of the dead persons as is shown in Fig.4. The reason of the redundancy is that individual differences for the decisions are randomly added according to the damage levels in the signaling case. Signaling is a subjective method and the best way to tell others of one's reality.

However, the realities are different from each other on AIE. So signaling alerts include some noises, and in the worst case, they cause moral hazard problem. On the other hand, positioning information monitoring is an objective method and partly eliminates AIE problems like moral hazard.

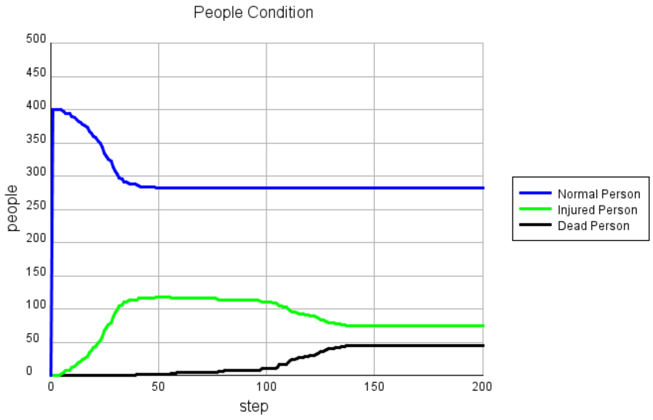

Fig. 8. Timeline of the numbers of the injured and the dead

Timing analysis. Fig.8 shows the numbers of the injured and the dead. If we can rescue people before 100 step, the damage would be relatively small. If it would take 40 steps for rescue actions after the alert of signaling or monitoring, the alerts in the left bottom box in Fig.9 (0<MST<40, 0<SST<40) are useless. The alerts in the right bottom box (0<MST<40, 40<=SST) are effective owing to signaling alerts. The alerts in the right top box (40<=MST, 40<=SST) are also effective to start rescue.

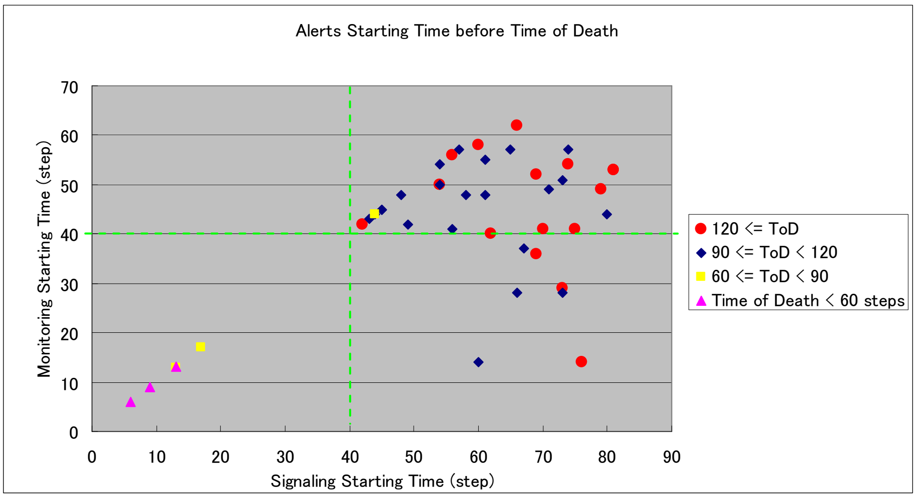

Fig. 9. Timing analysis: Alerts Starting Times before Time of Death

From the result, we found that: (1) Signaling contains noises because of the reasons such as moral hazard but it creates valuable information flows for quick actions. (2) Monitoring partly eliminates AIE problems but it sometimes causes delayed actions.

4.2 Simulation 2

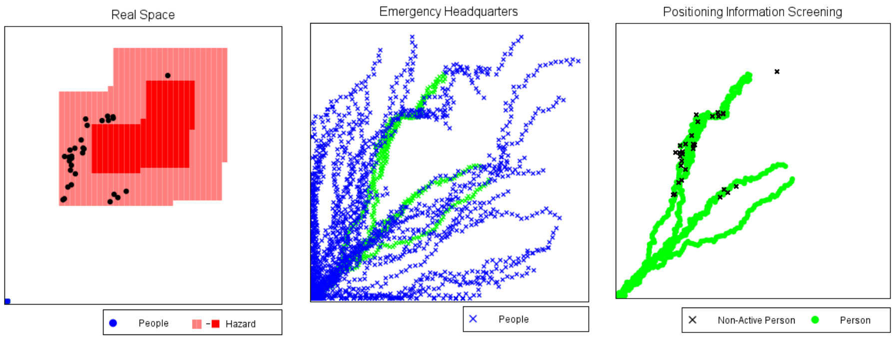

Fig. 10. Positioning Information Screening (step 200, Terminal Penetration 10%)

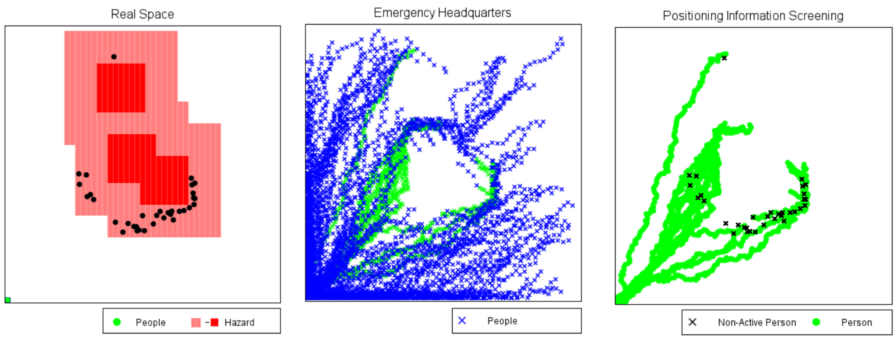

Fig. 11. Positioning Information Screening (step 200, Terminal Penetration 25%)

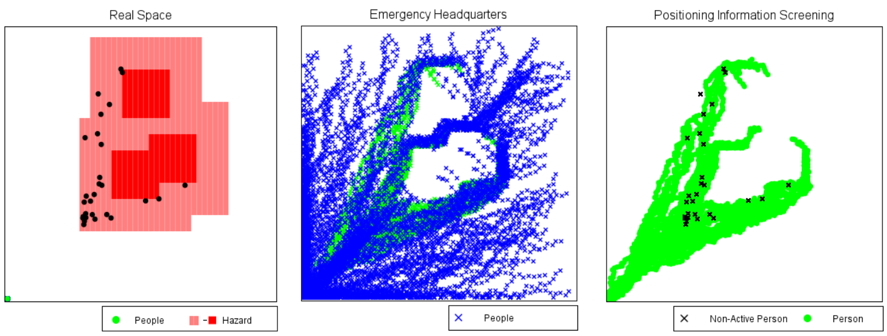

Fig. 12. Positioning Information Screening (step 200, Terminal Penetration 50%)

Fig.10, Fig.11 and Fig.12 show the results of positioning information screening test. In the simulations, we considered the reality of terminal penetration (TP). Only selected people who have the positioning terminals can be tracked by emergency headquarters (middle figures). We extracted the trails of injured persons (green area of the right figures) for the screening technique and seemed the green area as the targeted rescue area. Comparing the green screened area of trails and dead person's position (black dots in the left figures), we investigated the average coverage of dead person's position by the green area. We tried 10 times of simulations for each TP(10%, 20%, 25%, 50%, 75%). As a result, we have got Fig.13.

Analysis.

(1) If TP >= 25% i.e. more than one terminal device available for every four persons, more than 90% coverage was obtained. When TP = 20%, the coverage was 85%. It seems like a Pareto principle's curve. Using small data like positioning information and status information of agents, we can visualize the situations and take effective actions for cooperative works on AIE.

(2) If we use positioning information monitoring method in Fig.10, only 10 % of dead person could be detected stochastically. It is not an effective solution to grasp the panoramic situation of the disaster. We have to select the solutions with the case.

(3) From the results, we also found that the hazards are one of the constraints for the selection of the evacuation trails. If victims could take every path to the shelter, the coverage would be lower because everyone takes its path randomly. This analysis shows that we can adequately control people with constraints at disaster. It suggests that the clarification of evacuation routes is very important for R-DMSS. Education, drills and tools such as hazard maps also could be recommended solutions for safety measures.

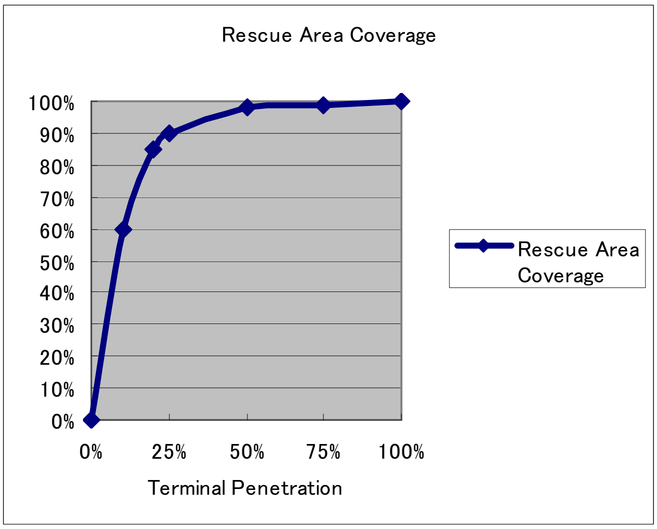

Fig. 13. Rescue Area Coverage

5 Conclusions

In conclusion, we have obtained the following from simulation experiments:

(1) Using small data like positioning information and status information of agents, we can visualize the situations and take effective actions for cooperative works on Asymmetric Information Environment.

(2) Communication techniques on AIE such as signaling, positioning information monitoring and positioning information screening are effective for geospatial analysis of cooperative works on AIE. Because they can create information flows to create actions. We have to select the techniques according to the case.

We can increase values from information flows by increasing effective actions for cooperative works using AIE-oriented systems design.

In future, we will make the simulation model more complex by adding more realities such as maps, route guidance information for evacuation, multiple shelters, rescue activities, hazard prediction information and other factors. More communication techniques on AIE should be tested including signaling from emergency headquarters. Real field experiments are to be followed in our plan.

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