Multi-agent Approach for Return Route Support System Simulation

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Keywords: Multi Agent, Mobile Agent, Ant Colony Optimization, Mobile Ad Hoc Network, Contingency Plan, Risk Management.

Abstract: We propose a system that supports stranded commuters caused by a large-scale disaster. When a large-scale disaster breaks out, buildings may collapse and roads may be damaged and the public transportation systems would be paralyzed. Thus, people working in the city center have to walk back home on foot. The problem is that when those people start walking, the situation along the routes for returning home may be different from that of the pre-disaster. Not only may it be the first time for most of them to walk home, but also the return route may be extremely complex due to many detours. They have to look for alternative routes whenever bridges collapse and fires break out. Making situation become worse, modern people intensively use navigation systems, those systems may be unavailable due to the paralyzed Internet. A large scale disaster may destroy base stations of wireless phones, and even if it does not completely destroy them, extreme congestion may paralyze the communication infrastructure so that not only net-surfing using smartphone, but also collecting information by e-mail may become impossible. To deal with such situations, we are designing a system that provides those unfortunate pedestrians appropriate return routes to their homes without depending on the communication infrastructures. Instead, our proposed system only depends on smartphones of those pedestrians and constructs mobile ad hoc networks (MANET) to collect and disperse useful information. We employ multiple mobile agents extensively for information collection and dispersion. In order to demonstrate the feasibility of our system, we have constructed a preliminary prototype of the simulation system and have conducted numerical experiments.

1 INTRODUCTION

When the Great East Japan Earthquake occurred in 2011, we observed many cracks and liquefaction phenomena on the ground as well as communication infrastructure broke down even far from the directly affected areas, i.e. Tokyo. Tokyo is more than 300km south of Sendai, a major city close to the seismic centre, even though the centre of the shock was the sea bed. Those phenomena made public transportations paralyzed. On top of the unfortunate events, the communication network became unreliable due to the collapse of base stations and congestion of communication networks. The situation made people who started walking home be unable to collect information such as the state of the return routes using the Internet. A large number of stranded commuters had to return home without any information. In a modern society, too many people rely on the communication network environment and depend on information gathering from the Internet. It is not difficult to imagine that how hard and dangerous for those modern people who heavily depend on the Internet, e.g. the navigation systems, to suddenly start walking without any Internet assistances. They may have to face possible secondary disasters.

Actually, there are several services that provide return routes for people walking back home. For example, Mapple ON provides an application for returning home support map when a disaster occurs (Mapple ON Co., Ltd., 2013). This application guides the user to support facilities such as first aid stations as well as provides return route to homes by using GPS information. This application utilizes the information such as road networks. This system, however, uses the information before a disaster occurs. Therefore when the disaster makes some roads impassable, the recommended routes by using

Taga, S., Matsuzawa, T., Takimoto, M. and Kambayashi, Y.
Multi-agent Approach for Return Route Support System Simulation.
DOI: 10.5220/0005819602690274
In *Proceedings of the 8th International Conference on Agents and Artificial Intelligence (ICAART 2016) - Volume 1*, pages 269-274
ISBN: 978-989-758-172-4

the map information become useless. We need a guiding system that uses the real-time information without Internet support.

In this paper, we propose a return route support system that uses real-time information collected by not using the Internet. That is a system temporarily constructs a MANET environment that connects the smartphones for communication means and makes them share useful information for returning home. The system collects as well as shares the latest information in the MANET using mobile agents for sharing it. By using the collected information, the system derives a certain return route for each person. Henceforth, we call this disaster return home route support system simply "the system", and the stranded commuters to take advantage of this system "the users".

When the user finds an impassable point of a road, he or she is expected to dispatch a mobile agent to spread the information to share it with other users. In order to collect information for the return route, the user dispatches another mobile agent to smartphones in the destination direction to look for useful information. Thus, the user can obtain the optimal return route in light of the current road conditions.

It is essential to use map information for deriving the return route. In the post disaster environment, however, it is difficult to acquire the map information from the Internet services. In this system, the user is expected to register the map data that covers the home and office before the disaster occurs. This way, the system can deal with the map information in a disaster.

The structure of the balance of this paper is as follows. The second section describes the background and discusses the related works. The third section describes the multi-agent system that is the basis of our proposed system. In order to demonstrate the feasibility of our system, we have constructed a prototype of the simulator for this system and have conducted numerical experiments. We report the results and discuss the future works in the fourth and fifth sections. Finally we conclude our discussion in the sixth section.

2 BACKGROUND

As we start our study, there are two major studies closely related to our system. One is the return route generation methods proposed by (Abeta et al., 2007). In order to assist people who return home in a disaster, their system collects the trajectories of stranded commuters using an ad hoc network, and proposes return routes using the trajectories. The users can then obtain the recommended moving directions through their mobile phones from the terminals associated to nearby intersections. By numerical experiments, they have showed that they have succeeded to derive good return routes.

The other one is Alejandro Aviles's ERAM (Evacuation Routing using Ant Colony Optimization over Mobile Ad hoc Networks) (Alejandro et al., 2013). In his study, in order to derive the evacuation routes, he employs a multi-agent system and the ACO (Ant Colony Optimization) in an assumed MANET environment. In his simulation system, when an evacuee successfully exits the building (the system assumes to be used indoor), a mobile agent called goal agent (GA) is generated from the smartphone the evacuee has. The generated GA moves to the other smartphone and records the number of movements. The number of movements acts as the pheromone in the ACO. The fewer the movements, the better trajectory the system evaluates and route seeking agents are probabilistically attracted. Routing Agent (RA) is the route seeking mobile agent that is also generated from the evacuee's smartphone. RA moves to the other smartphones and records the number of movements of the GA. Then the RA recommends the optimal evacuation route as the trajectory of the GA that has the least number of movements.

Asakura et al. have investigated the way information is exchanged between evacuees in a disaster. They have constructed a map information sharing system (Asakura et al., 2011). In their system, some evacuees record road information while moving to shelters, and then exchange the information they have collected using a MANET. Since the situation can change from time to time in a disaster area, they have proposed an ACO-based extension to allow evacuees to respond to such changes (Asakura et al., 2013).

In our proposed system, we have also introduced MANETs and multi-agent system. A MANET is a communication network formed by only mobile terminals. The difference between existing communication systems and MANETs is that MANETs do not require the base stations. When a large-scale disaster occurs, it may become difficult to conduct communication using the base stations. In addition, communication failure may also occur due to congestion. Therefore, MANET is suitable for constructing a temporary communication means without using the base stations. We have taken advantages of Wi-Fi for constructing communication links between smartphones. One of the disadvantages of MANETs is the fact that links are disconnected frequently because smartphones that constitute the network are literary moving. We can mitigate this problem by using mobile agents. Mobile agents are software agents that move between devices. Mobile agents provide a means of communication where connections are intermittent, because connections are only needed when they move. Thus, it is not necessary to keep connections during the entire communication processes.

In addition, we have employed the concept of the pheromone in the ant colony optimization (ACO) (Dorigo et al., 1996). ACO is an algorithm that mimics the foraging behaviour of ants. When ants move back and forth between food and nest, they deposit a chemical substance called pheromone. Pheromone evaporates over time. The ants following the pheromone trace to reach the food also deposit pheromone. As a result, the route that connects from the nest to the food in the shortest path receives more pheromone before its evaporation than other longer routes, and thus the most convenient route is established.

Even though we have proposed the base algorithm of this system in the previous paper (Yatsuyanagi et al., 2014), the simulator based on the algorithm was too crude, and the study failed to produce reasonable return routes. In this proposed system, we succeeded to derive a reasonable path by using Dijkstra's algorithm (Dijkstra, 1959) in which the intersections are treated as the nodes.

3 AGENT SYSTEM

In this system, we adopt an agent system comprising multiple mobile software agents. In the agent system, there are two types of agents. One is mobile agents that move among the users' smartphones: they are the routing agent (RA) and the information diffusion agent (IDA). The other is static agents that remain on the users' smartphones: they are the information agent (IA) and the node management agent (NA).

The roles of the mobile agents are collecting information while moving among the smartphones in the MANET as well as diffusing the newly discovered information such as impassable points and first aid stations. The roles of static agents are storing and organizing information that is conveyed by the mobile agents, and deriving the routes to the destinations based on the collected information, as well as providing user interface for receiving input from the users. Figure 1 shows the relations between these agents. We describe each agent in detail in the following subsections.

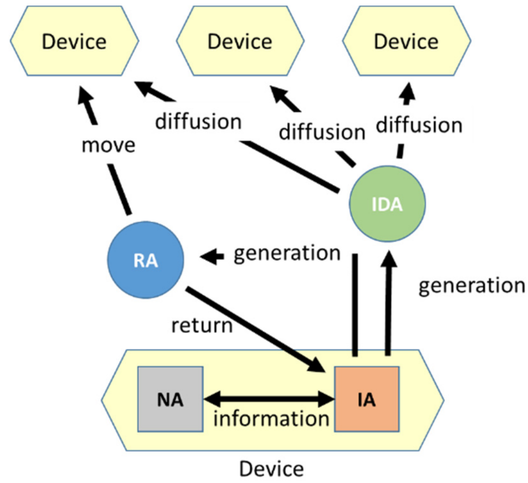

Figure 1: Information agent (IA) generates and dispatches RA and IDA for collecting and diffusing route information.

3.1 Information Agent (IA)

The roles of IA are providing the user interface, generating mobile agents, and deriving the return routes.

First, we describe the user interface. IA displays the derived route on the map with useful information such as impassable points and first aid stations. When the user finds an impassable point or a first aid station, he or she presses the corresponding diffusion button on the screen so that IA creates an IDA to diffuse the newly discovered information. IA updates the information on the map as RA returns and gives IA new information.

Second, we describe the generation of mobile agents. IA periodically generates RAs for collecting information. When the IA generates an RA, it requests NA and receives the destination location and the ID of the smartphone of the user. After passing the information to the RA, the IA dispatches the RA toward a smartphone in the direction of the user's destination. The RA then moves from a smartphone to another smartphone, and comes back with collected information. When RA comes back, IA receives the information from the RA and passes it to NA. Then it generates another RA after a certain time elapses. If RA has not come back after a certain time period, IA regards the RA as lost, and generates a new RA. When RA generated by another smartphone arrives, IA requests NA, receives information and passes it to the RA with its own ID. IA controls all the information transfers.

When the user presses the diffusion button, IA generates an IDA. When IA generates an IDA, it passes type information and location information to indicate what and where the user finds along with the ID of the smartphone to the IDA, and dispatches it to one of the smartphones nearby. Then, the IDA is gradually diffusing into the set of other smartphones. When an IDA generated by another smartphone arrives, IA receives the information and passes it to NA, and gives its ID to the IDA.

Third, we describe the route derivation. IA derives the route to the destination by using the collected information. While the default destination is set to the home, the system switches the destination to the rest area after certain time has elapsed since system startup, in order to give the user a break. The user can choose whether the switching occurs and duration time for switching. IA derives the return route by Dijkstra algorithm, and then displays it in the map on the interface screen. If IA receives information of an impassable point on the current route, it re-derives a new route that avoids that point. IA also re-derives the route when destination is altered.

3.2 Node Management Agent (NA)

NA keeps the collected information and passes the information to IA on request. The stored information includes GPS information representing the current location, the current destination, the impassable locations, the first aid stations and the location of the rest areas along with the time they are stored and the IDs of the IDAs that convey the information. When redundant information is delivered, NA deletes the old information by referring to the time information. Also, after a certain time period from the store, the old information is deleted.

3.3 Routing Agent (RA)

RA is the harbinger of the user. It conducts reconnaissance of the direction toward the destination and collects the information.

RA is generated by IA. Then RA moves to one of the smartphones that is in the user's moving direction. Upon arrival at such a smartphone, RA requests the IA on the smartphone to provide information that it has. Upon receiving the information, RA moves again to another smartphone. After repeating this moving operation some predetermined number of times, it tries to return to the original smartphone. Since each RA has the history record of the visited smartphones as a sequence of IDs, RA can move back to its origin by tracing the recorded smartphones. If a link of the smartphones is lost, it waits to between for the link to recover for a while. After waiting for a predetermined period, and if the link is not recovered, the waiting RA self-destructs. When RA succeeds to return to the original smartphone, it passes the collected information, and disappears. Figure 2 shows how an RA moves.

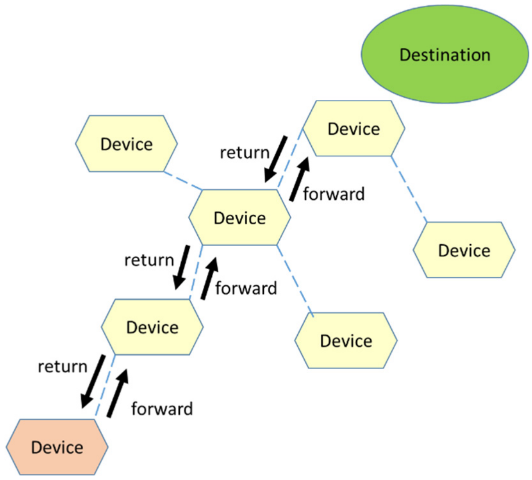

Figure 2: RA’s movements.

3.4 Information Diffusion Agent (IDA)

IDA diffuses useful information such as impassable points on roads and bridges, resting places and the first aid stations the user finds. IDAs collectively implement the information sharing among the users.

When the user presses one of the diffusion buttons on the interface screen, IA produces an IDA. The IDA has the information about what the user finds the location and the time. Then, the IDA clones itself to number of smartphones that are linked to the originating smartphone. One copy moves each of the neighbour smartphones. IDA has a unique ID and all the IDs of the duplicated IDAs are the same. Upon arrival, IDA passes its information and its ID to the IA of the smartphone it arrived to and it clones itself again to all connected smartphones. If its ID is already stored, the IDA self-destructs without doing anything. By doing so, IDA prevents dispersing redundant information. Also, each IDA disappears after a certain number of movements.

IDAs collectively implement the pheromone in ACO. IDA determines the value of its information according to the distance between the discovery point and the current position, the number of movements it performed, the elapsed time from it was generated. In other words, IDA reduces the value of its information as the number of movements, the elapsed time, the distance between the discovery point and current position increases. When the information value gets to be below a certain threshold, the IDA gets to be useless and self-destructs.

4 PRELIMINARY EVALUATION

To demonstrate the feasibility of our proposed multi-agent system, we have constructed a simulator and have conducted preliminary experiments on this simulator.

The scenario of the simulator is as follows; after a disaster occurs, the users move through a city, in which a few impassable points exist, to the destination using this system. Figure 3 shows a screen shot of the simulator that displays the users (red dots), an impassable point (purple area), a safety zone (green region), and the links between the smartphones (connecting lines between the users).

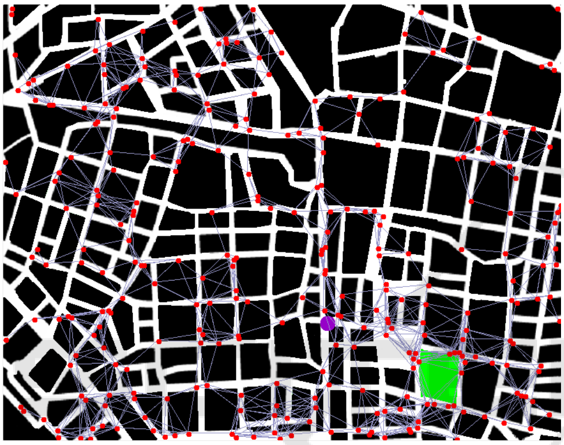

Figure 3: Simulator screen.

The number of users can be specified. Each user's smartphone has certain residual quantity of the battery power remaining that is randomly set. When the battery is dead, the user has to stop moving. Each smartphone has certain communication range, and when a user with a smartphone comes into communication range, a link is automatically established. When a user finds an impassable point (comes within a certain view range), he or she diffuses that information with GPS coordinates to other users by dispatching IDAs. The users, who receive that information by an IDA, as well as the discoverer, try to find alternative routes to detour the impassable point.

We have set two cases. In one case, all the evacuees have smartphones equipped the system, and in the other case, no one uses the system. We have performed the simulation experiments ten times each and compared the averaged consuming rounds for all the users' arrivals to the destinations. One round means the duration time all the users execute one step. In the experiments, we set the number of users 300, the field size 800 × 625 pixels, and 2 pixels per round as the amount of movement of a user.

Table 1 shows the results of the experiments. Since the users who use the system are aware of the impassable points on the route in advance, those who use the system can arrive earlier to their destination than those who do not use the system, as expected.

Table 1: Result.

	Num. of rounds
Evacuation with the system	583
Evacuation without the system	683

5 DISCUSSIONS

Even the preliminary experiment shows the system is feasible and effective; we have to investigate quite a few problems in order to make the simulation system be realistic.

A smartphone has limited resources. In the present design, if the users observe many impassable points, they dispatch many IDAs. Thus each smartphone in the system may be overloaded. We have to consider how to save the battery consumption due to the heavy computational load of each smartphone. In order to mitigate this problem, we can restrict the inflow of IDAs. In order to set the threshold to restrict the inflow, IA should sense the environment and set the most appropriate value. However, that method may have IA overloaded by heavy computations. Therefore, it may be better to set a threshold in advance. It is difficult to evaluate the appropriate values for various environments. It is the next step we have to take by implementing much more refined simulation of how the respective methods affect the system's performance.

In the present system, RA is designed to go back to the smartphone where it was created by tracing back its movement history record. Therefore, if RA cannot find one of the smartphones in the record, it cannot return to the origin. There are many factors that cause the trace of the smartphone to be lost: the user of the smartphone may go somewhere, the user may terminate using the system, and the battery of the smartphone may be dead. In the simulator, the user does not terminate the system until either he or she succeeds in reaching the safe area, or the battery of the smartphone dead. However, in reality, when the battery capacity is running low, the user usually switches off the smartphone to save the battery. Therefore the possibility the RA loses the trace may be higher in reality than in the simulator.

In order to solve this problem, we are planning to provide alternative return routes for the RA that are different from the ones in the movement record. For example, when a RA arrives at the destination smartphone, then the RA acquires information of other smartphones connected to that smartphone. If the RA cannot find the next smartphone in the movement record, it moves to another smartphone that is connected to the smartphone that may be connected to the scheduled destination. By doing so, we can increase the possibility of each RA to reach to the original smartphone even if a RA cannot find the smartphone in the movement record. However, this technique imposes more burdens on RAs and may causes performance degradation in the system.

In a wider context, Stranders et al. proposes decentralized coordination algorithms for multiple sensors (Stranders et al., 2009), and Zambonelli's SAPERE project is pursuing a pervasive services in context-aware systems (Anzengruber et al., 2013; Montagna et al., 2013). Their approaches are similar to our proposal approach even though none of them considers using MANET and mobile agents. We plan to re-design our system after collecting data from the simulation, and we will then integrate the concepts of such competitive systems.

6 CONCLUSIONS

In this paper, we propose a return route support system for stranded commuters going back home. The system consists of smartphones connected through MANETs. The users of smartphones can exchange and share useful information by using multiple mobile agents. In order to examine the feasibility, we have constructed a prototype of the simulator and have conducted a preliminary experiment. As we have expected, the users who use the system can arrive to the safe area more quickly than the users who do not use the system. As a future direction, we are refining the simulator to investigate the problems discussed in the fifth section. For this purpose, it is necessary to increase the capabilities of the simulator. In particular, we are implementing a new simulator where the system perceives the traffic of people and adjust its behavior dynamically.

ACKNOWLEDGEMENTS

This work is supported in part by Japan Society for Promotion of Science (JSPS), with the basic research program (C) (No. 25330089 and 26350456), Grant-in-Aid for Scientific Research.

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