Analysis of Pedestrian Navigation using Cellular Phones

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Abstract. Navigation services for pedestrians are spreading in recent years. Our approach to provide personal navigation is to build a multi-agent system that assigns one guiding agent to each human. This paper attempts to demonstrate a design implication of the guiding agent. In the navigation experiment where a pedestrian using a map on a GPS-capable cellular phone was guided by a distant navigator, we observed the communication between them by conversation analysis. The result suggests that information required by a pedestrian were the current location, the current direction and a proper route toward a destination. The communications between a pedestrian and a navigator were based on a navigation map or a movement history. When a pedestrian did not understand the map adequately, navigation sometimes failed due to the lack of communication basis.

1 Introduction

Traveling in an unfamiliar city is a daily task for ordinary people. For instance, they look for meeting spots or shops in unfamiliar cities. These days, more and more pedestrians use cellular phones as information sources for route guidance. Pedestrians use cellular phones in two ways as information sources. One is displaying a map showing the current location, and the other is consulting with a distant navigator via voice conversations.

Due to the popularity of and improvement in sensor devices and network devices, environments that support ubiquitous computing are spreading. In such environments, it is possible to provide personal navigation that suits the properties, the location and the context of each user [1]. We built evacuation navigation system based on multi-agent server, which assigns one guiding agent to each human. In this system, an agent can provide a personalized navigation map considering the current location and the surrounding environment [2][3].

Some people may not be able to reach their destination even if they use such navigation systems. People who are not good at reading maps should ask others for help. This paper assumes that pedestrians take part in evacuation drill with

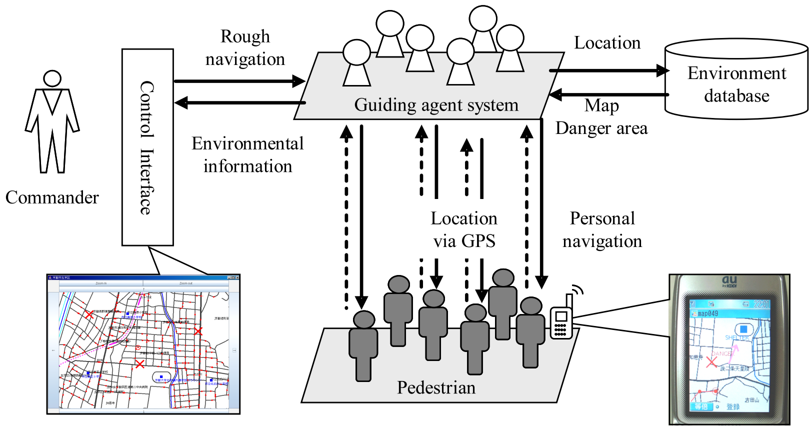

Fig. 1. Large-scale evacuation guide system with guiding agents

the evacuation navigation system. To demonstrate requirements of the guiding agent, we address the following two issues.

Analysis of information required by pedestrian To examine a design implication of the guiding agent, it is necessary to investigate the information requirements of pedestrians when they use a navigation map.

Analysis of communication between pedestrian and navigator A pedestrian cannot be always guided into a proper route by a distant navigator. Investigation of failure cases is needed in order to examine the limitation of remote navigation. We analyze the communication between the pedestrian and the navigator using conversation analysis[3].

2 Large-Scale Evacuation Guide System

We produced a large-scale evacuation guide system based on large scale agent platform and GPS-capable cellular phones. Fig. 1 depicts system architecture of pedestrian navigation system [3]. In a navigation system which uses ubiquitous information infrastructure on a city, the system can acquire information of each individual user in real time. However, quantity of the information becomes enormous. There occurs a problem that a human who control system cannot handle all the information. Our approach is that a human gives rough navigation to agents and the agents give precise navigation to each person. We aim at realizing a mega scale navigation system using GPS-capable cellular phones.

The control interface was implemented based on transcendent communication architecture. Transcendent communication is proposed as the method for

[3] Conversation analysis is a methodology for studying social interaction. It was principally developed by Harvey Sacks and Emanuel Schegloff [4].

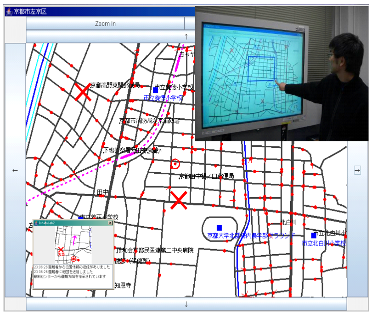

Fig. 2. User interface of navigation system

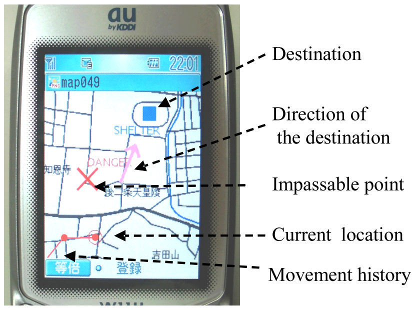

Fig. 3. Navigation map on cellular phone

navigation in public spaces [5]. In transcendent communication, the distribution of evacuees in the real space is reproduced on the virtual space as human figures that mirror the positions of evacuees; the positions of the subjects are acquired by sensors. The system commander assigns evacuation destinations and evacuation directions through the control interface shown in Fig. 2. The commander issues high level instructions to the guiding agents using a map.

The guiding agents that assigned to evacuees on a one-to-one basis provide individual navigation maps via GPS-capable cellular phones. An agent is instructed on a direction of evacuation by the control center. The agent retrieves shelters around the user, and selects a destination according to the ordered direction and distance between the user and each shelter. The agent also obtains the surrounding environmental data from a database. Then, the agent sends their users personalized navigation map showing a destination, the direction, impassible point, the current location and the movement history as indicated on Fig. 3.

3 Experiment of Pedestrian Navigation

3.1 Overveiw of Experiment

We conducted two navigation experiments in which pedestrians were guided by distant navigators using the large-scale evacuation navigation system. These experiments have two purposes. One is to investigate the information required by pedestrians, and the other is to analyze communication between the pedestrian and the navigator. May et al. already examined information requirements in an experiment of navigation based on turn-by-turn strategy [6]. However the human subjects did not take along a map showing the current location in the research.

We analyzed the information requirements with *think aloud method* [7] which was to observe what human subjects behave and think. The method has actually been applied to experiments in navigation systems. In the method, an experimenter instructs human subjects to think aloud while performing tasks. The experimenter observes the human subjects' behavior and thinking at the same

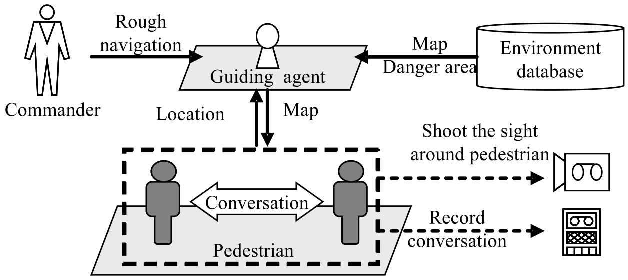

Fig. 4. Experiment 1: observation of conversation between pedestrians

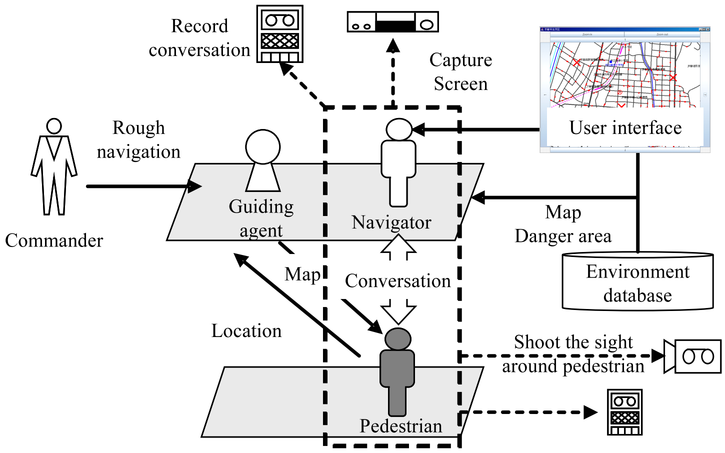

Fig. 5. Experiment 2: observation of conversation between pedestrian and navigator

time. The experimenter can combine human subjects' behavior with their feelings about the system which they have in mind. In these navigation experiments, we observed two kinds of conversations.

Observation of conversation between pedestrians The pedestrians used navigation system which provided a map as Fig. 3. In the first experiment, we let human subjects to use system in pairs and instructed them to talk to each other (Fig. 4). We refer to this experiment as *experiment 1*.

Observation of conversation between pedestrian and navigator In the second experiment, pedestrians used the navigation system and consulted with distant navigators via voice conversations (Fig. 5). We instructed pedestrians to talk to navigators anytime they have a question. We call this experiment as *experiment 2*.

In order to analyze the relativity between the conversation and the behavior, we needed to gather actions, speeches and eye sights of human subjects.

Following three data were collected; 1) recordings of the conversations between pedestrians and pedestrian or pedestrian and navigator, 2) video pictures of the behavior of pedestrians, 3) video pictures of the sight pedestrians have seen.

In experiment 1, a cameraman followed a pair of pedestrians and shot their behaviors with video camera. We recorded speeches of the pedestrians with attached microphones and transmitted them to the video camera by Bluetooth audio transmitters. In experiment 2, a cameraman followed a pedestrian and shot his behavior with video camera as in the case of experiment 1. Maps provided to pedestrians and navigation screens were recorded by DV video recorder. Conversations between the pedestrian and the navigator were also recorded with call-recording microphone. After the experiments, the graphic data was synchronized with the voice data.

3.2 Scenario of Experiment

We assumed the scenario that a huge earthquake struck around Kyoto University and dwellers escaped to shelters using navigation system through GPS-capable cellular phones. We chose a evacuation drill as scenario for the reason that pedestrians must choose their route carefully and more depended on the system than usual. We preliminarily set disaster points and subsequently added secondary disaster points during the experiment in order to make route selection difficult and to make pedestrians behave carefully.

The direct distance from a start to a destination in the experiment was about 1.5 km. The number of human subjects performed as pedestrians was four. All of them were students and unfamiliar with the testing area. Additionally, they had no experience using the evacuation navigation system. In experiment 1, the pedestrians performed the task in pairs so that we gathered two groups of data. In experiment 2, the pedestrians performed the task alone so that we gathered four groups of data.

3.3 Task and Instruction

In experiment 1, pairs of pedestrians left start points and headed for destination points. They consulted a map showing the current location on a cellular phone and talked to each other on their travel. In experiment 2, pedestrians had two cellular phones so that they could consult with a distant navigator in parallel with reading a map. When they have any questions or any troubles, they could consult the navigator to resolve it.

In experiment 2, the task of a navigator was to answer questions from a pedestrian. The navigator was expected to make the maximum efforts to answer any questions from a pedestrian. The navigator should use information on the navigation system sufficiently. An information screen for a navigator is shown in Fig. 2. A navigator could view environmental information about a local area, the current locations of pedestrians and a map provided to a pedestrian. Considering those information, the navigator guided the pedestrian via voice conversation. The navigator answered the questions consulting a screen of navigation system.

A: ((The corner to turn is)) here? What do you think about that? B: Further, isn't it further? Because it is still A: What? But it ((= map)) has not reloaded yet. B: I see.

Table 1. Conversation about current location

Experimenters who were familiar with the experimental area acted as navigators. Additionally they had practiced guiding pedestrians beforehand. They guided pedestrians one-on-one in the experiment. The purpose of the experiment is to analyze what kind of information pedestrians required. Therefore a navigator must not speak to a pedestrian voluntarily.

Pedestrians ware expected to be aware of the necessity to select routes carefully and to be encouraged to voice what they are thinking in these experiments. To ensure it, we gave the instructions below to the human subjects in the experiments; "This is an evacuation drill. Pedestrians are expected to act carefully and to commit themselves to reach shelters in safety", "Disaster points are impassable so that pedestrians must avoid them".

4 Result and Analysis

4.1 Information Required by Pedestrians

Conversations about questions, confirmations and trouble were extracted from pedestrians' speeches and transcribed. These transcripts were categorized according to pedestrian's intentions or pedestrian's demands. The result shows that the pedestrians required information about the current location, the current direction and a proper route to a destination. The information was used to confirm and trust a route as well as decide it. The information required by pedestrians are categorized into the following three types.

Current location In Table 1 case, pedestrians could not have the confidence in correspondence between a map and the real world. Such cases were frequently observed when pedestrians could not recognize the corner that they had decided to turn as reading a map in advance.

Current direction In Table 2 case, pedestrians could not understand a map properly because of losing sense of direction. Sense of direction was important for understanding maps.

Proper route toward destination In Table 3 case, pedestrians were not only aware of the current location and the current direction but also read the map properly. However they had no concrete idea which route is optimal.

We describe the details about the three kinds of information with the transcripts that actually observed in the experiment. In the following transcripts, 'P:'

A: So, ((should we read the map)) in this direction? ((should we go)) in this way?
B: This way.
A: Is this OK?
B: eh?
A: ((We should read this map)) in this direction, don't you? Yes, yes, because we are walking this way now.
B: This way, this way, it's bad to read the map as it is.
A: Yes, it is.

Table 2. Conversation about current direction

A: Which route? This one?
B: How about downside? ((See the road heading southward)) this way?
A: I agree. Because the danger zone exists over there, this way is better

Table 3. Conversation about route selection

means an utterance of a pedestrian and 'N:' means an utterance of a navigator. Number in parentheses indicates elapsed time in silence by tenth of seconds and a dot in parentheses indicates a tiny gap within or between utterances. A phrase bracketed by '()' means unclear speech. A phrase bracketed by '(())' means a supplement by us. The plural sentences started with '[' means that they are started at the same time. ':' shows sounds are stretched or drawn out (number of : indicates the length of stretching). ',' means continuing intonation. '?' means rising intonation and '.' means closing or stopping intonation.

4.2 The Failed Case of Verbal Navigation

Questions about route selection were most frequently observed in experiment 2. A navigator tried to guide a pedestrian, but the navigator sometimes could not guide him to a proper route. Hereinafter, we discuss failure cases of verbal navigation and analyze why they failed communications.

Table 4 shows an example of failed navigation caused by a navigator that could not recognize a situation of a pedestrian. In Table 4, the pedestrian asked the navigator about route selection (see line 2). In the case, the navigator could not understand the pedestrian's situation and failed to navigate the pedestrian (line 4-11). The navigator ended the conversation with an instruction to check the current direction using the movement history. The map on a cellular phone showed an instruction to go southward but the pedestrian lost sense of direction and wrongly started going eastward as saying "I start walking randomly" (line 13). The conversation was started with the request for route guidance but the navigator could not meet the pedestrian's demand. The navigation failed due to the difficulty for the navigator to check the pedestrian's situation in the case.

1	((Pedestrian stops just after departure and ask the route to navigator))
2	P: Now, which direction ((to go))? (0.5) Should I turn at first, leaving the park?
3	(1.6)
4	N: Well:, Can you see a road (.) heading southward straight?
5	P: ((starts walking))Southward,((look around))((turn back))
6	P: Well, maybe.
7	(0.6)
8	N: Well, hard to fi:nd?
9	P: Yes. I can't grasp the direction.
10	(0.4)
11	N: Well.
12	(0.9)
13	P: Oh, now (.) I start walking randomly.

Table 4. Failure case of navigation caused by obscurity of pedestrian's situation

A map on a cellular phone was reloaded every one minute. Location measurement and a server access took about 15 seconds on the navigation system. Consequently, the map was updated every 75 seconds. Additionally, location measurement via GPS sometimes has a gap between the current location shown on the map and the current location in the real world. Resolving the gap, the navigator was required to ask some questions to the pedestrian about the pedestrian's situation at first. However, when the pedestrian was lost and asked the navigator for guidance, it was difficult for the navigator to get actual information from the pedestrian. The failure cases are considered to be caused by the lack of common basis between the pedestrian and the navigator.

4.3 The Successful Case of Verbal Navigation

Table 5 shows a transcript of information sharing based on a navigation map. First, the pedestrian asked the question "Does this bold black line mean this big street?" (see line 1). This question implied that the pedestrian believed to read the same map as the navigators. The navigator said "Go slightly leftward" (line 14) for guiding the pedestrian. The word "leftward" did not indicate "left side of the body (=eastward)" but "left side of the map (=westward)" in this conversation. In a word, he meant that the pedestrian had to go westward in the instruction. The pedestrian properly interpreted this confusing instruction and started heading westward without hesitation. It appears that they used the map as basis. Such a instruction was typical case when a pedestrian used maps and voice conversations.

Navigations based on a movement history also occurred several times in experiment 2. As described in section 4.2, a navigation based on a movement history sometimes failed due to the difficulty of understanding the pedestrian's situation. On the other hand, a navigation based on a navigation map often suc-

1 P: Does this bold black line mean this big (.) street?
2 N: Yes.
3 (3.3)
4 P: ((turn right)) We:[ll,
5 N: [If you go straight,
6 (0.4)
7 P: Yes.
8 N: Well, fire [disaster, you will face the fire disaster,
9 P: [Do you mean fire disaster?
10 P: I see.
11 N: Go, (.) slightly leftward.
12 P: OK.

Table 5. Navigation based on navigation maps

ceeded because they can use the map as concrete common basis. Misconceptions were not likely to occur as long as a pedestrian can read maps properly.

4.4 Design Implication of Guiding Agent

We demonstrated that the kinds of information required by pedestrian were the current location, the current direction and a proper route toward a destination. Pedestrians wanted information related to the current situation but it is difficult to understand it by communication with a distant navigator. Therefore the navigation system is required to enable to check conditions of a pedestrian. Pedestrians who truly need the verbal navigation are ones who are bad at reading maps. We can support the map recognitions of such pedestrians who have a high tendency to get lost. With proper map recognition, the pedestrians can receive smooth verbal navigation from a navigator.

Pedestrians could not be convinced their location even if they could get their current location via GPS. Because GPS system had little measurement error and navigation system delayed of about 75 seconds for updating a navigation map. We can improve latter point to enable mobile phone to cache the static data and to receive only dynamically changing data.

Pedestrians also could not be convinced their current direction. Guiding agents calculate their current direction based on the movement histories. However, when a they just leaving a start or turning a corner, it is difficult for a guiding agent to calculate the current direction from the movement history. These days, cellular phones with electronic compasses are spreading. The system can capture precise direction of a pedestrian easily with them.

In addition, pedestrians wondered which route they should select. Because there ware plural courses that can arrive at a destination. For supporting route selection, guiding agents should be equipped a function to show a route which is suited to user preferences (e.g. movement distance or a number of turns).

5 Conclusion

Our approach to provide personal navigation is to build a multi-agent system that assigns one guiding agent to each human. This research attempts to demonstrate a design implication of the guiding agent. In the navigation experiments in which a pedestrian using a map on a GPS-capable cellular phone was guided by a distant navigator, we investigated the communication between them by conversation analysis method. The problems we tackled in this work are as follows.

Analysis of information required by pedestrian We examined the information required by pedestrians using the navigation system. The result indicated that pedestrians required information about the current location, the current direction and a proper route to a destination.

Analysis of communication between pedestrian and navigator Navigation maps and movement histories were used as communication basis in successful cases. When a pedestrian did not understand a map adequately, navigation sometimes failed due to lack of communication basis.

In this research, we analyzed the information required by pedestrians and the limitation of remote navigation using maps and voice conversations. Future works include determining how to reflect the result of this experiment to the guiding agents and how to support people who are not good at reading maps.

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