Master Thesis

Remote Navigation of Pedestrians using Location Information and Voice Conversation

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February 8, 2007

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Abstract

Navigation of pedestrians using cellphones is a common practice today. Typical example of that is a navigation system using GPS, which obtains users' position and provides suitable maps for the situation. It is getting popular with the diffusion of GPS-capable cellphones.

The navigation methods using pedestrians' location have the advantage and disadvantage. We can provide real-time information according to the situation of pedestrians with the method. Therefore, they are expected to be used for not only daily navigation but also navigations in uncertain environment such as disaster or large scale event. But it is hard to navigate pedestrians who are bad at reading maps with the methods only using maps .

The navigation methods using voice conversation are also popular. With the methods, pedestrians can ask the navigator any questions they have. Therefore, pedestrians bad at reading maps can get enough information by voice conversation. But there is also a disadvantage that the navigator cannot recognize pedestrian's location and direction adequately. That causes misunderstanding and misguidance of the pedestrian.

With existing cellphones, pedestrians are unable to use GPS-function and voice conversation in parallel. However, that will be capable in the near future. In this study we researched two points below to find effective design of navigation system under the condition of the kind.

Merit and Problem of the Navigation Style We started with the research of how the two information source are used efficiently by the pedestrian. We also found the case navigation fails and why it fails.

Requirement for Navigation Systems Using Location Information and Voice Conversation To solve the problem found, we investigated what kind of functions are required for the navigation systems using cellphones.

To research them, we re-created navigation system using location

information and voice conversation with two cellphones. Then we conducted two experiments below and navigated subjects with the system.

Comparative Experiment with Existing Navigation System We compared two pedestrian navigation systems. One uses only maps generated by location information. And the other uses voice conversation with navigator at the same time. In this experiment, we analyzed the subjects' behaviors and conversations to reveal what kind of information pedestrians need and how the information is provided. To observe the information needed, we applied an experimental maneuver letting two subjects act together and observed the conversations between them.

Comparative Experiment to Research the Effect of Direction Assistance We drew a following hypothesis from the first experiment - "With an assistance of direction sense, pedestrians get to read the maps adequately, and that leads effective use of voice conversation". To confirm the hypothesis, we introduced direction assistance to the navigation system and performed an experiment to investigate the effect.

The contribution of this study is as follows.

Clarification of the Merit and Problem on the Navigation Using Location Information and Voice Conversation We found that pedestrians and navigators often use maps as a basis of verbal navigation through voice conversation. We also found that in the cases where pedestrian do not understand maps adequately, navigation sometimes fails due to the lack of basis.

Clarification of the effect of Direction Assistance We confirmed that some pedestrians feel more secure with the use of compass. We also confirmed that it is not enough just to offer the way to check the direction. In some case, the pedestrian cannot recognize the timing to check the direction and gets lost.

The conclusion is that, when we use a navigation system using location information and voice conversation, it is effective to prepare means to check the direction. And in such occasions, it is desirable for the system to lead pedestrians into checking direction and location when necessary.

位置情報と音声会話を用いた歩行者の遠隔誘導

大石 隆俊

内容梗概

今日では，携帯電話を用いた歩行者の道案内が日常的に行われている．代表的なものは GPS を利用して歩行者の位置情報を取得し, 現在地から目的地までの誘導地図を配信するという歩行者の道案内サービスで，GPS 携帯電話利用者の増加に伴って普及が進んでいる．

歩行者の位置情報を利用した誘導には，歩行者の周囲の状況に応じたリアルタイムの情報を提供できるという利点がある．そのため，日常の道案内だけでなく，災害時やイベント時の群集誘導などの刻一刻と変化する環境の中での歩行者誘導に利用することが期待されている．

しかし，地図を歩行者に一方向的に配信するだけでは，地図を読むことが苦手な歩行者を誘導することが難しいという問題点がある．

また，携帯電話の音声通話機能を利用した，歩行者と誘導者との対話による道案内も日常的に行われている．対話による道案内では歩行者が誘導者に自由に質問をすることができ，地図が苦手な歩行者に詳細な誘導情報を提供できるという利点がある．しかし，誘導者が歩行者の状況を知ることが難しいため，認識のずれに起因する誘導ミスが起きやすいという問題点がある．

現在の携帯電話では地図配信と音声通話を同時に利用することはできない．しかし，近い将来この 2 つの機能を同時に，相補的に利用することが可能となることが予想される．本研究では位置情報と音声会話を併用できる環境下での歩行者の効果的な誘導方法を明らかにするため，以下の 2 点を調査する．

位置情報と音声会話を用いた誘導の利点と問題点　初めに，誘導時に位置情報と音声会話という 2 つの情報源がどのように使われ，どのような相乗効果を持つのかについて調査を行う．また逆に，この誘導方法を用いても解消できない問題点と，その問題が発生する要因についても調査を行う．

位置情報と音声会話を用いた誘導システムの要件　位置情報と音声会話を併用する誘導手法の利点と問題点を明らかにしたうえで，その問題点を解消し利点を活かすために，携帯電話を使った誘導システムにどのような機能が求められるのかを明らかにする．

本研究ではこの 2 点を調査・分析するため，位置情報と音声会話を併用した誘導システムを擬似的に再現し，被験者にこのシステムを利用しながら移動を

行わせる 2 つの実験を実施した．

既存の誘導方法との比較実験　被験者が位置情報を基にした誘導地図だけを利用して移動を行う場合と，それに加えて誘導者との音声会話が利用できる場合（本研究で提案した誘導方法）の 2 つの条件で実験を行い，両誘導方法を比較した．この実験では移動中の被験者の行動と会話内容を分析して，歩行者が移動中にどのような情報を必要とするのか，またその情報が提案した誘導方法によってどのように歩行者に提供されるのかを調査した．歩行者がどのような情報を必要としているかを観測するため，被験者に 2 人 1 組で誘導システムを実行させ，その被験者間の会話を分析する手法を用いた．

歩行者の方向感覚支援の効果の調査実験　上の実験結果から，「歩行者が自分の向いている方向を確認できるようになると地図を理解しやすくなり，目的地への移動というタスクを達成しやすくなる」という仮説を立てた．この仮説を検証するため，誘導地図と音声会話に加えてコンパスを利用できる場合に，被験者の行動がどのように変化するかを調査する比較実験を行った．

実験の結果得られた本研究の貢献は以下の通りである．

位置情報と音声会話を併用した遠隔誘導の利点と問題点の明確化　位置情報と音声会話を併用した遠隔誘導方法では，位置情報を使って作成された地図を誘導者－歩行者間の基準として使いながら，音声会話によって移動経路の説明がなされることを確認した．また，歩行者が地図を正しく読めていない場合には両者の間で位置の基準が取れなくなるため，音声会話を使用しても誘導に失敗する場合が多いことが確認された．

方向感覚支援の効果の確認　歩行者が常に自分の方向を確認できるようにすることで，移動中の安心感が向上し，移動ルートの間違いが減る場合があることを確認した．また，単に方向確認の手段を提供するだけでは，歩行者が適切な場面で方向の確認を行わないために，道を間違える場合があることを確認した．

以上の結果から，位置情報と音声通話を併用した誘導を行う際には，同時に方向確認の支援を行うことが効果的であるといえる．方向感覚の支援を行う際には，単に向きを確認する手段を用意するだけでなく，歩行者が実際にその手段を使って，方向を確認するように意識を向けさせることが重要である．

Remote Navigation of Pedestrians
using Location Information and Voice Conversation

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Chapter 1 Introduction

Moves in unfamiliar environments are common practices for us today. For instance, we sometimes look for meeting spots or friends' houses we have never been to.

In most cases of move like that, we consult information source while walking. We consult maps or route guide memorandums when searching friends' houses. And we use cellphones while searching for acquaintances in a crowd.

As mentioned in the latter example, cellphones are increasingly being used as tools for route guidance today. Actually, we often see people searching meeting points with cellphones in their hands. We also see people reading maps on their cellphones while looking for routes.

By using cellphones as tools for route guidance, we can provide practical information to the pedestrians. If we use route guide memorandums or paper maps as guidance information, pedestrians can only use static guide information. In case of navigation using static information, the pedestrian must comprehend the information depending on his condition like location or direction. In contrast, when we use cellphones as tools for route guidance, pedestrians can notify their conditions to the navigator or navigation system. This will help the navigator or navigation system to provide guidance information depending on pedestrians' conditions. More concretely, they can provide maps around pedestrians and they also can solve pedestrians' problem through voice conversation.

There are two kinds of pedestrian navigation method using cellphones today. One kind uses location information and the other kind uses voice conversation.

Major example of the former is a navigation system providing maps generated from location information. In this system, pedestrians send their location information to the server by using GPS-capable cellphones and receive maps around them. The system is put in practical use as a route guidance service and getting popular with the diffusion of GPS-capable phones now.

We can provide route guidance and local information around pedestrians at the same time by using maps. Therefore navigation system using location information is expected to be useful for guidance in case of disasters or massive events. But there is also disadvantage. It is hard to navigate pedestrians who are bad at reading maps with the methods only to use maps for navigation.

Popular example of the navigation using voice conversation is the phone conversation between pedestrian and navigator, which is common practice for us today. By using voice conversation, pedestrians can ask the navigators anything they wonder. Therefore, pedestrians bad at reading maps can get enough information. But there is a disadvantage that navigators cannot recognize pedestrian's condition enough. That causes misunderstanding and causes misleader.

With existing cellphones, it is incapable of using GPS-function and voice conversation in parallel. However, that will be capable in the near future. In this study we researched two points below to find effective design of pedestrians' navigation system under the condition of the kind.

Merit and Problem of the Navigation Style We started with the research of how the two information source are used efficiently by the pedestrian . We also found the case navigation fails and why it fails.

Requirement for Navigation Systems Using Location Information and Voice Conversation To solve the problem found, we investigated what kind of functions are required for the navigation systems using cellphone.

To research them, we re-created navigation system using location information and voice conversation by using two cellphones. And we conducted two experiments to navigate subjects with the system.

The contents of the following chapters are below. Chapter 2 describes the previous works about remote navigation system and the way to realize the navigation system using location information and voice conversation in parallel. Former part of Chapter 3 explains the experimental methodology and setting to find out advantage and disadvantage of the navigation method. And latter part of Chapter 3 shows the result of the experiment and discussion. Former part of Chapter 4 explains the setting of experiment to test the hypothesis proposed from the discussion in Chapter 3. And latter part of Chapter 4 shows the result of the experiment and analysis. In Chapter 5, the requirement of remote navigation systems using location information and voice conversation is discussed based on the results of the two experiments. Finally, Chapter 6 describes the conclusion of the study.

Chapter 2 Navigation of Pedestrians

There have been many previous researches about the communication in pedestrians' navigation using location information or voice conversation. In this chapter, some of these works are introduced first. And then the communication on the navigation method using location information and voice conversation is described. Finally, the system architecture to realize the method is discussed.

2.1 Navigation Method using Voice Conversation

In this section, some previous researches about the navigation using voice conversation are introduced. In [1], the verbal communication between pedestrians searching exit in virtual indoor space is analyzed. The occasion when pedestrians need other's help by telephone is researched in [2]. And the communication in route guidance using only voice conversation is analyzed in [3].

In the experiment conducted in [1], several subjects acted as pedestrians and got together to find out an exit in a maze built in virtual space. The purpose of the experiment is to analyze the verbal communication between pedestrians and correlation between pedestrian's behavior and spatial perception. The experiment showed that the pedestrians who behave in company frequently mention their surrounding environments and directions. And it was also shown that these pedestrians had good recognition on their searching space and could draw relatively accurate image maps of the maze. Based to the results, it can be said that use of voice conversation assists pedestrians' space recognition in walking.

In the experiment conducted in [2], subjects walked in unfamiliar to the distant goal using route guide memorandums. The subjects were permitted to use verbal route guide service on telephone when they need other's helps. The purpose of the experiment is to find out the occasion when pedestrians need other's help on telephone. The experiment showed that pedestrians need other's help to make sure whether the route they are following is right. It also showed that pedestrians prefer passers to the navigator as information sources despite the fact that the navigator's guidance is more accurate than passer's. This is due to the difficulty for remote navigator to explain right way to the pedestrian through voice conversation. Based to the results, it is necessary to design the navigation system assisting route guidance between the navigator and the pedestrian smoothly.

The communication in the route guidance using only cellphones is analyzed in [3]. In such kind of navigation, navigator often make instructions with the words "right" or "left" and the instructions are based on the direction of the pedestrian. But the navigator cannot know the pedestrian's direction actually. That causes inconsistency between "expected direction" and "actual direction", and leads misguidance. Additionally, in such cases the navigator sometimes does not notice the inconsistency in spite of verbal confirmation of pedestrian's position . Therefore the misguidance goes on for long.

2.2 Navigation Method using Location Information

There also exist many previous researches about the navigation using location information. The navigation system letting pedestrians input location information by themselves proposed in [4]. In other research [5], the navigation system using GPS-capable cellphone is proposed. Using GPS-capable cellphone, the pedestrian sends location information to the system and the system sends back detailed map around him. There is also a commercial navigation service using GPS-capable cellphone[1].

In [4], the navigation system using pedometer and magnetic sensor as location sensor is proposed. The system indicates the direction and distance to go with voice and pictures at the beginning. And it senses pedestrian's pathway by pedometer and magnetic sensor. After reaching indicated point, the pedestrian pushes buttons on the system and new destination point is indicated by the system. The system guides the pedestrian by repeating this process. It was tested by an experiment that pedestrians can be guided correctly by the system. But it was also found that some subjects in the experiment could not

[1] EZナビウォーク : http://www.au.kddi.com/ezweb/service/ez_naviwalk/

retrace the way they walked through [6]. This navigation method is effective in guiding pedestrians to the routes prepared beforehand, but not to any other routes.

In [5], the pedestrian send his location to the system using GPS-capable cellphone. And then the system guides him by providing customized map. The system generates maps every time pedestrian access it so pedestrian can get not only route guidance but also local information around. By providing local information, the system can be available for guidance in case of disasters or massive events. Actually, an experiment assuming evacuation guidance had conducted with the system.

In [7], it is said that pedestrians using maps shows less mistakes than ones using text route guide. But there are some people who are bad at reading maps and it is difficult to navigate them only with maps. Actually [8] indicates that those who evaluate themselves bad at reading maps prefer text guidance to maps. Moreover, the experiment conducted in January 2006 with the navigation system of [5] saw some subjects lost due to misleading of maps.

2.3 Remote navigation using location information and voice conversation

Pedestrian's space recognition in walking is improved by the use of voice conversation. And it has an advantage to be available for navigating those who are bad at reading maps. But the navigator cannot recognize the pedestrian's direction with voice conversation. That causes inconsistency between "expected direction" and "actual direction", and leads misguidance.

On the other hand, the use of location information has an advantage to lead less misguidance but it cannot guide pedestrians bad at reading maps.

If we can use these two navigation method in parallel for navigating pedestrians, it is expected that the navigation will go better. The navigator only provide maps as long as pedestrians can read them well. And when the pedestrians cannot read maps, they can use voice conversation to ask the navigator anything they wonder.

It is conceivable that the navigation method using location information and

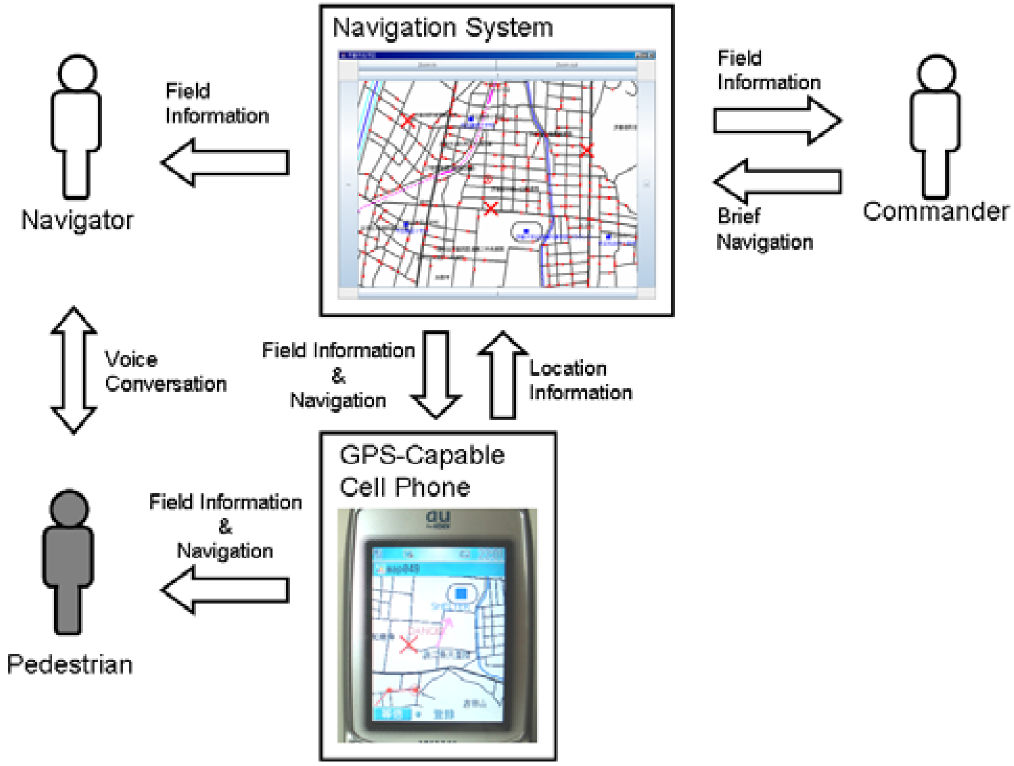

Figure2.1 : Architecture of Navigation System using Location Information and Voice Conversation

voice conversation is superior to the methods using just one of them. One reason is that the former has simply more information source than the latter. And another reason is that by using two methods at the same time, the navigator and the pedestrian can use location information as bases of verbal navigation.

The architecture of navigation system using location information and voice conversation is shown in figure 2.1.

The navigation system manages information needed to navigate pedestrians. It shows real-space information (e.g. locations of pedestrians, impassable points) on screen by bird's-eye view. The human commander consults these information and gives brief instruction to the pedestrians using touch panel. When the commander does not give any instructions, agents on the navigation system gives instructions automatically,

There also exists human navigator who gives detailed navigation to the pedestrians. He consults the screen and navigates the pedestrians verbally by telephone. It is called "transcendent communication [9]" to give instruction while consulting location information. And there is a previous researched about using the method for navigation in indoor space. By using transcendent communication, grasp of local information and detailed navigation of pedestrians can be achieved at the same time.

With the navigation system using transcendent communication, the pedestrians only consult maps as long as they can read them well. And when they cannot read maps, voice conversation is available to ask the navigator anything they wonder.

There has been some researches about remote navigation using location information and voice conversation. Transcendent communication on the indoor space navigation is analyzed in [10]. The effect of voice conversation for pedestrians with maps is researched in [11].

In [10], the navigation in only indoor space is mentioned, and the location information is only used by the navigator. On the other hand, we mention the navigation in large outdoor space. In addition, the location information is also presented to the pedestrians as maps.

Also in [11], the location information is only used by the navigator and the pedestrians cannot use location information.

The navigation method mentioned in this study differs from previous works in that the pedestrians can use both of voice conversation and location information.

2.4 Remote navigation system using location information and voice conversation

With existing cellphones, pedestrians are unable to use Web browser and voice conversation in parallel. Therefore we re-created navigation system using those two functions by using two cellphones. With this system, the pedestrian use one cellphone to send location information to the server. And then he use another one to use voice conversation with the navigator. We took navigation system in [5] to provide maps to pedestrians. The followings are the details of

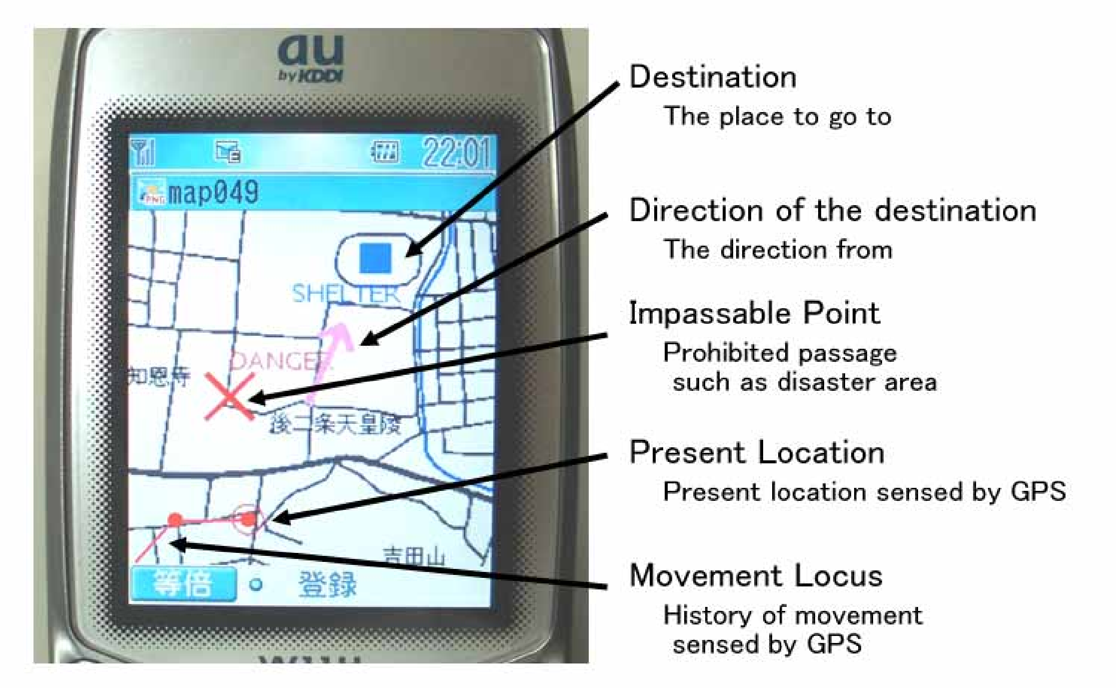

Figure 2.2 : Navigation Map on GPS-capable Cellphone

the system.

An example of maps provided to the pedestrian's GPS-capable cellphone is shown in figure 2.2.

The content on the screen is described as HDML (Handheld Device Markup Language) document. A map like figure 2.2 appears when the pedestrian access the navigation system.

The destination, direction of destination, impassable points and movement locus appear on screen as well as the map and present location.

The map is automatically reloaded every 1 minute even though the pedestrian takes no action. And if he wants to get the latest information immediately, manual reload is also available.

The information screen for the commander and navigator is shown in figure 2.3. The commander consults the local information and location information on the screen and decides the direction to guide the pedestrians.

There are also maps provided to the pedestrians on the screen. The navigator consults these maps to check the information pedestrians have and then navigate them in conversation.

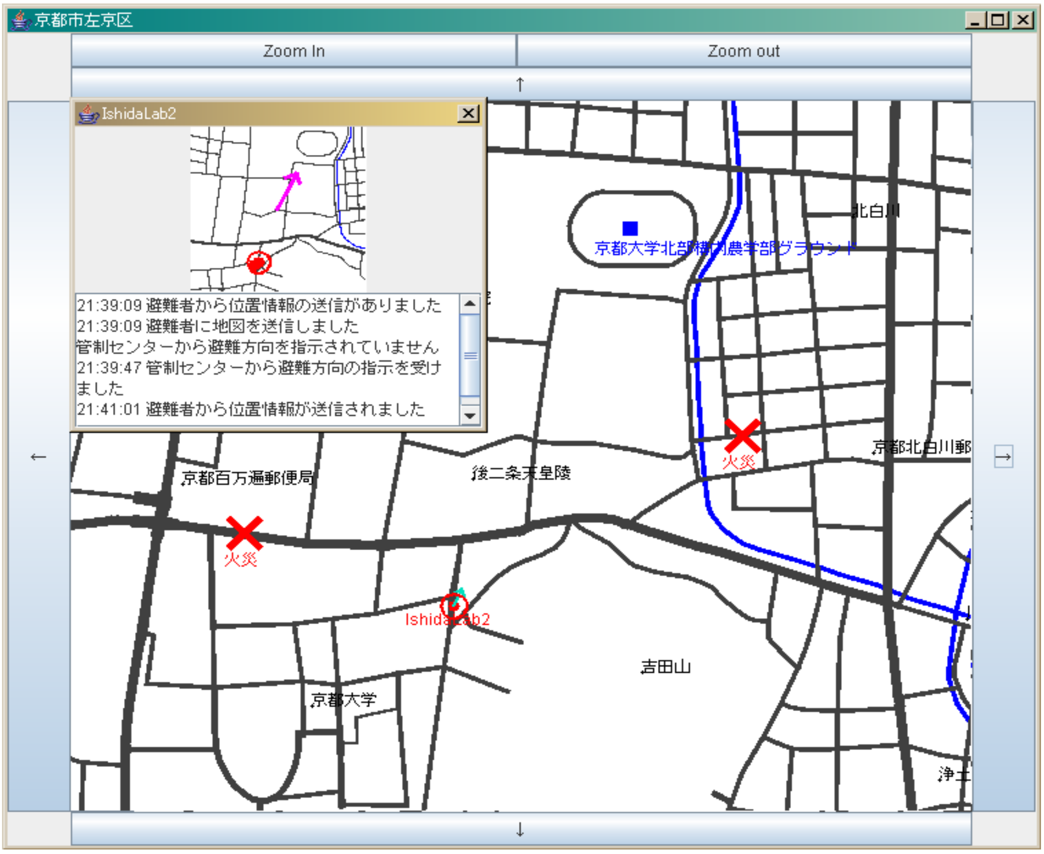

Figure 2.3 : Screen of Navigation System

Chapter 3 Analysis of Pedestrian Navigation using Location Information and Voice Conversation

We conducted an experiment to reveal the effect of the navigation method using location information and voice conversation. In the experiment we compared the method with common existing method which uses only maps generated from location information. Two trials are conducted using those two methods and we analyzed the behavior of the pedestrians.

3.1 Objective of Experiment

The objective of the experiment is to analyze the following two points.

・ **Advantage of the Navigation Method using Location Information and Voice Conversation**

We assume that with the navigation method mentioned, the pedestrians who are good at reading maps should consult only maps. And those who are bad at reading maps should use voice conversation to ask the navigator anything they wonder. One of our concerns is to analyze the benefit arising from the navigation like that. For the purpose, we compared two navigation methods, one uses maps and voice conversation and the other uses maps only.

At first we analyzed the kind of information needed by pedestrians in walking by observing pedestrians' speech in the experiment. And next we analyzed how the information is given to the pedestrians by observing their speech and behavior.

・ **Cause of Failure in Navigation using Location Information and Voice Conversation**

It is expected that there still exist some cases of failure even with the navigation method using both of location information and voice conversation.

We researched when such failure happens and analyzed why it happens by observing the conversation between the pedestrian and the navigator.

3.2 Think Aloud Method using Observation on Conversations between Users

The purpose of the remote navigation system is to assist pedestrians' transition by providing information. Therefore when we are going to research the advantage and disadvantage of the system, it is necessary to observe what kind of information pedestrians need while using the system [12].

There is an experimental method termed "think aloud method"[13] which was designed to observe what subjects are thinking. With the method, the experimenter instructs the subjects to think aloud while performing tasks. And then the experimenter observe subjects' behavior and thinking at the same time. By letting subjects think aloud, we can combine their recognition on the system and the problems they have in mind. Think aloud method has actually been used in experiments on navigation systems [11].

Think aloud method has been used in many experiments on system evaluation such as usability testing. In the meanwhile, there is also a problem that it is too unnatural for the subjects to voice what they are thinking continuously [14]. In the experiment conducted outdoors, the subjects are to perform already complicated tasks. They have to use the system and pay attention to the environment around, in addition to thinking aloud. Therefore it becomes difficult letting the subject to voice what they are thinking.

In this experiment, we let the subjects talk with others while using the system instead of thinking aloud. By doing this, we could observe what they are thinking properly.

・ **Observation of Conversation between Two Pedestrians**

Originally, the system is designed for single use. But in the experiment using only maps for navigation, we let the subjects to use system in pairs and instructed them to talk to each other. We observed and analyzed the conversation between them.

・ **Observation of Conversation between Pedestrian and Navigator**

In the experiment using maps and voice conversation, we instructed the navigator not to talk to the pedestrian. On the other hand, we instructed the pedestrians to talk to the navigator anytime they have a question. By that, we

Figure 3.1 : Think Aloud Method using Observation on Conversation between Users

can observe all the problems pedestrians have in the form of question. We recorded the questions and analyzed them.

An appearance of the experiment observing conversation is shown in Figure 3.1. It is quite natural that some conversations appear while two subjects consulting just one cellphone. With the method, the subjects do not need to pay attention to speaking aloud what they are thinking.

3.3 Experimental Environment

The setting of experimental environment is described below.

3.3.1 Experiment Description

We prepared a scenario that huge earthquake had struck Kyoto city. We instructed subjects to escape to the shelter using navigation system through GPS-capable cellphones. We chose evacuation navigation as scenario for the reason that the pedestrians must choose their route carefully and depend on the system more heavily than usual.

The airline distance from the start to goal in a trial is about 1.5 km. The subjects participated in the experiment as pedestrians and they performed two trials. In one trial, the pedestrians used navigation system which only provides maps (we call this trial "trial 1.1" in following). In the other trial, they used the navigation system using maps and voice conversation (we call this trial "trial 1.2" in following).

3.3.2 Subjects

The subjects participated in this experiment as pedestrians. And experimenters who are familiar with the usage of the system acted as the commander and navigator.

The number of subjects was four. All of them were students and unfamiliar with the testing area. Additionally, they had no experience using the navigation system.

In trial 1.1 the pedestrians performed the task in pairs so we gathered two groups of data. And in trial 1.2 the pedestrians performed the task alone so we gathered four groups of data.

3.3.3 Task of Pedestrians on Trial 1.1

Figure 3.2 shows the map of testing area on trial 1.1. In the trial the navigation system used only maps for navigation. The pair of pedestrians left the start point and headed for the destination point. They consulted the maps

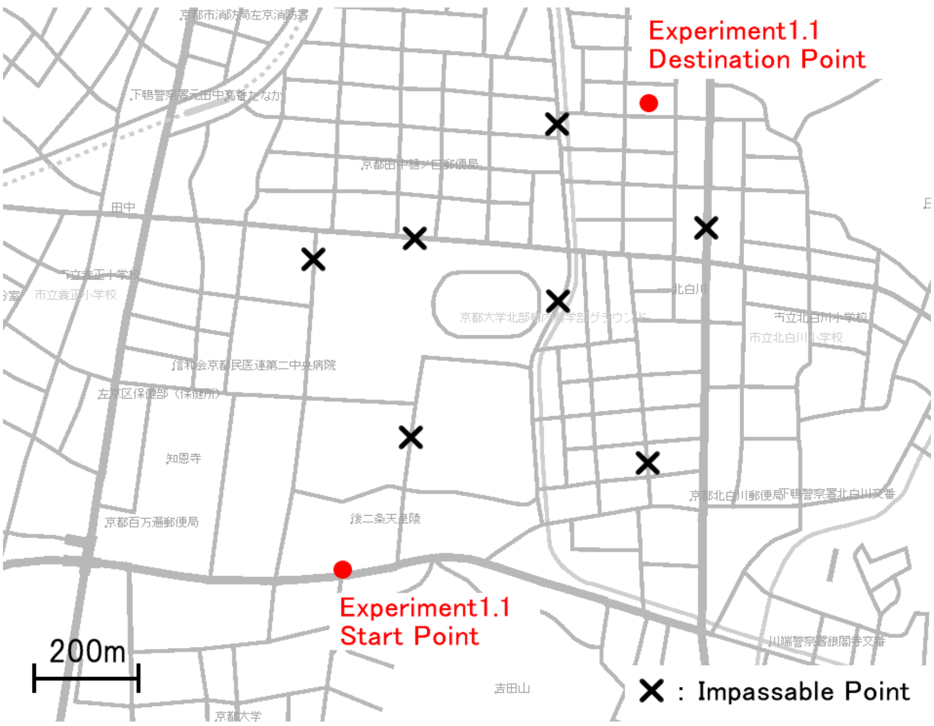

Figure 3.2 : Testing Area of Trial 1.1

on the cellphone and talked to each other on their movement.

We indicated the pedestrians that secondary disasters would happen in some points and they must avoid them. We actually set virtual disasters on the point marked X on figure 3.2, and indicated the points to pedestrians through the provided maps. We set the disaster points in order to make route selection difficult and make pedestrians behave carefully.

3.3.4 Task of Pedestrians on Trial 1.2

Figure 3.3 shows the map of testing area on trial 1.2. The pedestrian left the start point alone and headed for one of the destination points predetermined (one of the pair in trial 1.1 headed for destination A and the other headed for destination B).

The pedestrian had two cellphones and could use voice conversation in parallel with maps (see figure 2.1).

As well as trial 1.1, virtual secondary disasters occurred at the point marked

Figure 3.3 : Testing Area of Trial 1.2

X in this trial.

3.3.5 Task of Navigator

The task of the navigator is to answer the questions came from pedestrians on trial 1.2. He answered the questions consulting the screen of navigation system. The navigator was forbidden to speak to pedestrians voluntarily.

Two experimenters who are familiar with the usage of the system acted as navigators. Additionally they practiced guiding pedestrians beforehand. They guided the pedestrians one-on-one in the trial.

3.3.6 Task of Commander

The task of the commander is to give brief instruction for pedestrians to head for predetermined destination through the system. With this system the instruction is sent to pedestrians as maps. Therefore there are no direct communication between the commander and pedestrians.

An experimenter who is familiar with the usage of the system acted as the commander.

3.3.7 Instructions for Participants in Experiment

This experiment has two purposes. One purpose is to analyze what kind of information pedestrians need. And the other is to analyze how the information is provided to the pedestrians through navigation method using location information and voice conversation. Therefore it is necessary to research minutely what information the pedestrians wish on the system while moving.

For that purpose, following two points must be ensured.

1. The pedestrians should feel themselves being in a disaster area. And they must always be aware of the necessity to select routes carefully.
2. The pedestrians must always be encouraged to voice what they are thinking.

To ensure the points above, we gave the instructions below to the participants in the experiment.

Instructions for the Pedestrians

- This is an experiment of evacuation drill. The pedestrians are expected to act carefully and must commit themselves to reach the shelter in safety.
- Some virtual secondary disasters occur during moving. The disaster points

become impassable so the pedestrians must avoid them.

- In experiment 1.1, the pedestrians are expected to discuss any questions with the partner. Especially about issues easily cause collisions, they must discuss well and make agreements.
- In experiment 1.2, the pedestrians are expected to ask the navigator any questions they have. The navigator is good at guiding pedestrians and he always returns proper advice.

Instructions for the Navigator

- The navigator is expected to make the maximum efforts to answer any questions from pedestrians. Therefore the navigator should use the information on the navigation system sufficiently.
- The purpose of the experiment is to research what kind of information pedestrians need. For that purpose, the navigator must not speak to pedestrians voluntarily.

3.3.8 Data Acquisition Environment

In order to analyze the conversation and behavior of the subject we generally need three data, or the behavior, speech, and eyesight of the subject. In this experiment we collected following three data for analysis.

- Recordings of the conversations between pedestrians or pedestrian and navigator
- Video pictures of the behavior of pedestrians
- Video pictures of the sight pedestrians have seen

We must collect these data in the way to be able to synchronize them later. In what follows the data acquisition environment we have adopted is described.

The data acquisition environment of the pedestrians in experiment 1.1 is shown in figure 3.4.

In experiment 1.1, a cameraman followed the pair of pedestrians and shot their behaviors on video camera. We also recorded the speeches of the pedestrians with microphones and transmitted them to the video camera by Bluetooth audio transmitters. The two speeches are recorded separately on the two audio channels of the camera. By doing this, we collected the two pedestrians' behaviors and speeches at the same time.

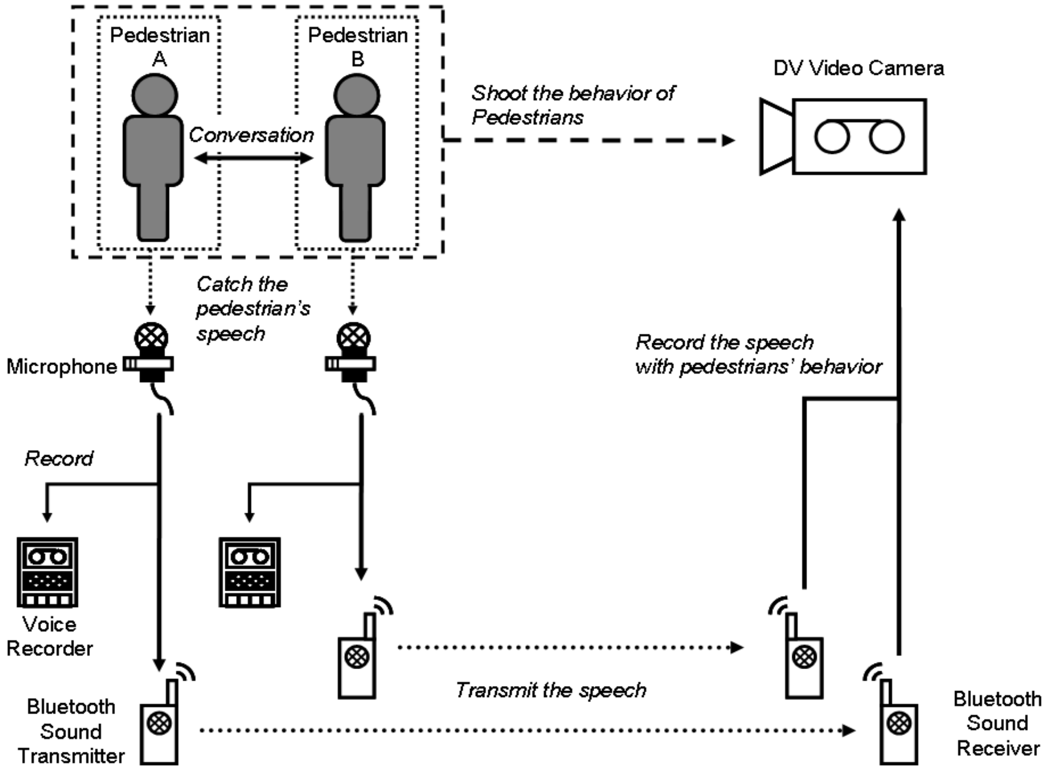

Figure 3.4 : Data Acquisition Environment of Pedestrians
in Experiment 1.1

We shot the pedestrians from behind so their behaviors and eyesight were also recorded at once. And we used Bluetooth transmitters to avoid restricting their behaviors with microphone cords.

We recorded pedestrians' speeches on the video camera using Bluetooth transmitter. But we also recorded the speech at the hands of pedestrians. In case of audio transmission failure, we complemented the speech with these recordings.

The data acquisition environment of the pedestrians in experiment 1.2 is shown in figure 3.5.

In experiment 1.2 we have to record both pedestrian's and navigator's speech. But in this environment we recorded only pedestrian's speech. The whole conversation was recorded at the hand of the navigator.

The data acquisition environment of the navigator and navigation system is

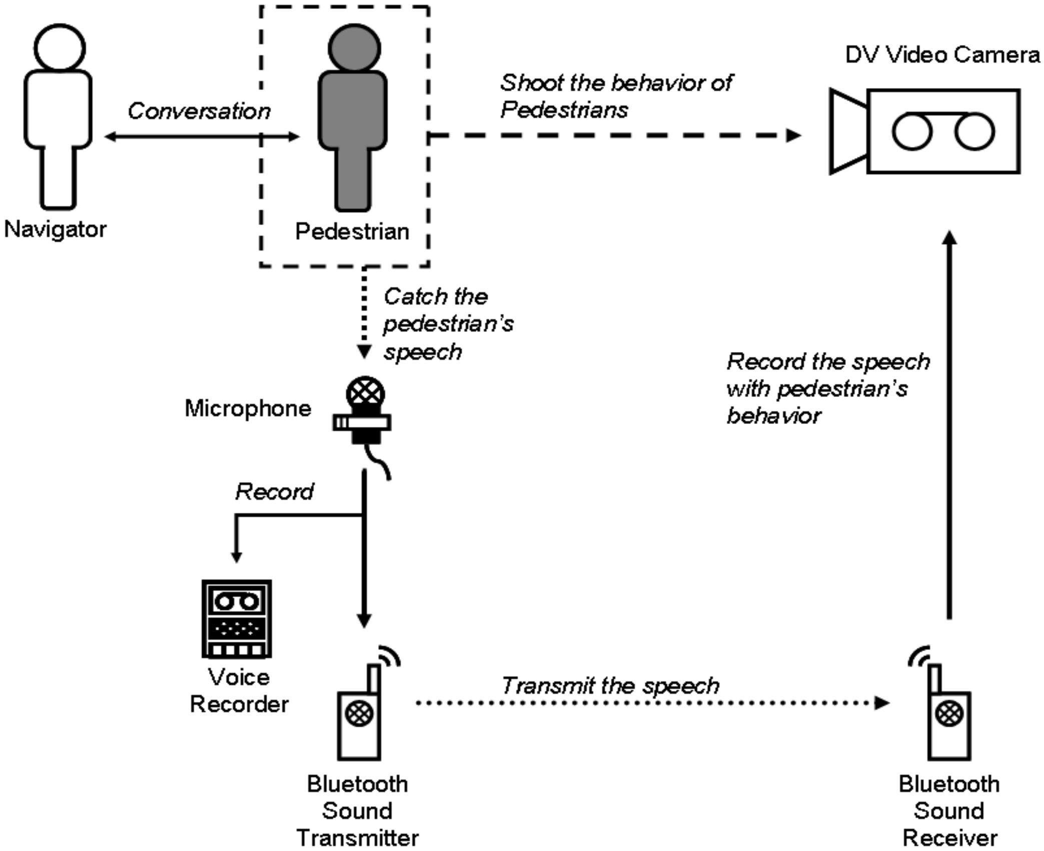

Figure 3.5 : Data Acquisition Environment of Pedestrians in Experiment 1.2

shown in figure 3.6.

The maps provided to pedestrians were recorded by DV video recorder. The conversation between the pedestrian and navigator is recorded at the hand of navigator using call-recording microphone.

3.4 Result and Analysis

We conducted the experiment described in the previous section and analyzed the data collected. We summarize the result of analysis below.

- **Advantage and Disadvantage of Navigation Method using Location Information and Voice Conversation**

We revealed that the pedestrians need three kinds of information. They are current location, current direction, and proper route to the shelter. It is certain that the pedestrians really want to know the routes out of the three.

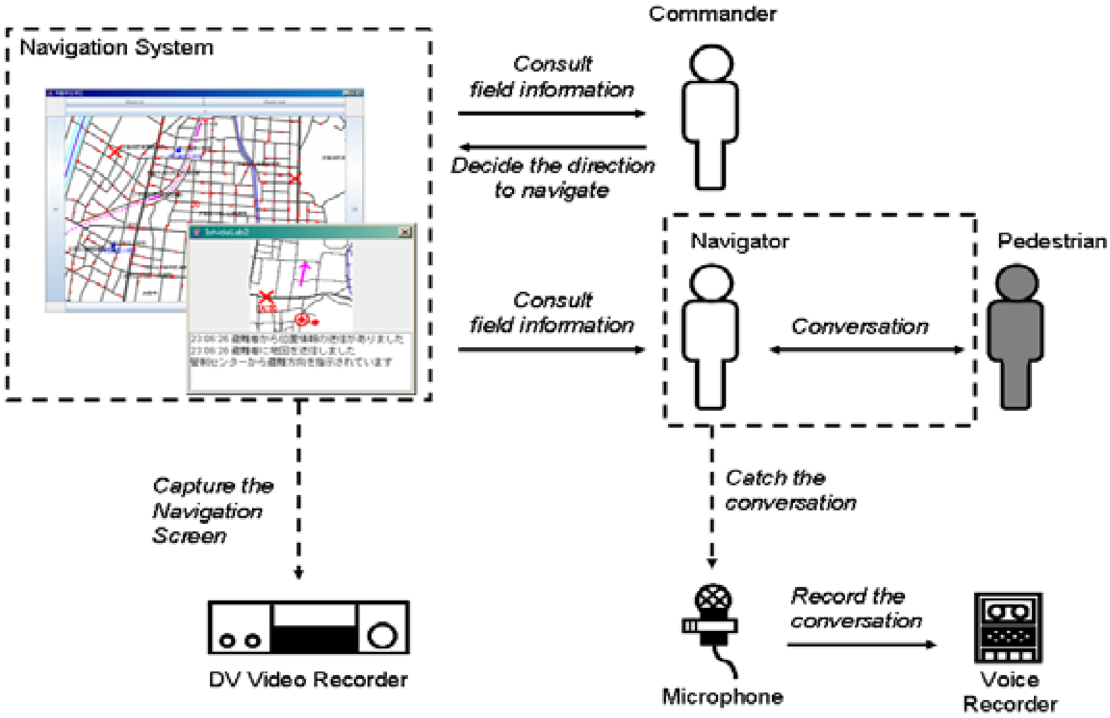

Figure 3.6 : Data Acquisition Environment of Navigator and Navigation System

We also revealed the advantage of the navigation method using location information and voice conversation. With the method the navigator and pedestrians can use maps as concrete bases of route guidance while using voice conversation.

・ **Failure Case of Navigation and the Causes**

The navigation failed in the cases that pedestrians did not recognize their current locations and directions. In such cases the navigator cannot know the situation around pedestrians so they failed to make bases for verbal navigation.

The detailed result of analysis and discussion are described in the following.

3.4.1 Information Needed by Pedestrians

From the speeches of pedestrians, we collect ones about questions, confirmations and trouble. And then we categorized them according to pedestrians' intentions, or the kind of information they wanted.

As a result, we found that pedestrians need information about current

A:((曲がる角は))ここ？どう思う？
((The corner to turn is))here? What do you think ?
B:まだ，まだじゃない？だってまだ
Further, isn't it further? Because it is still
A:え，でもこれ（(＝地図)）更新されてへんもん
What? But it ((= map)) is not reloaded yet
B:そっか
I see.

Case 3.1 : Conversation about Current Location

location, current direction, and proper route to the shelter. In the following we describe the details about these information with the transcripts of speeches actually found in the experiment.

The ":" marks in the following transcriptions mean the points speech is prolonged. And "><" mean the section speech is quicken. The number bracketed by "()" means long silence and its length in seconds. Short silence is represented as "(.)". Up-arrow "↑" means that the tone right before the mark is rising. Down-arrow "↓" means that the tone right after the mark is falling. The plural sentences started with "[" means that they are started at the same time. Ingressive sounds are described as "h" and egressive sounds as "hu". The section bracketed by "()" means unclear speech. And the sentences bracketed by "(())" means the supplement by the author.

The information pedestrians need are categorized into three kinds below.

1. Current Location

Case 3.1 shows the actual conversation of two pedestrians about current location.

Like this, some cases were confirmed in which pedestrian ask the partner for current location. In such cases pedestrians could not have the confidence in correspondence between maps and real space. Especially, the cases often confirmed where pedestrians could not recognize the corner they had decided to turn beforehand on the map.

A:え，これじゃあ，((地図を))こう見るの？やったらこっち？
Oh, so,((should we see the map)) in this direction? So, in this way?
B:こっちか
This way.
A:てこと？
It this OK?
B:（でもここ)，え？
(But this is), what?
A:てことじゃないん？そうやんそうやん，今だってこう歩いてるもん
Isn’t it so? Yes, yes, because we are walking this way now.
B:こう，こう，このまま見てしまったらあかんのか
This way, this way, it’s bad to see it as it is.
A:うん，そうな
Yes, I agree.

Case 3.2 : Conversation about Current Direction

A:どっち行く？こっち行く？
Which route? This one?
B:下，とか？（(南に向かう道を見る)）この道ってこと？
How about downside? ((See the road heading southward)) this way?
A:そやな．だってこっちが危険地帯やから，こっちの方が
I agree. As the danger zone exists here, this way is

Case 3.3 : Conversation about Route Selection

2. Current Direction

Case 3.2 shows an example of conversation about current direction. The pedestrians unconscious of directions are unable to read the maps properly either. So in such cases the maps do not work at all. Therefore it is important for pedestrians to recognize the direction.

3. Proper Route toward Shelter

Case 3.3 shows an example of conversations about route selection. In such cases the pedestrians were aware of current location and direction and read maps properly, but they had no concrete idea which route to choose.

Table 3.1 : Failure of Navigation Caused by Obscurity of Pedestrian's Situation #1

1	歩:	もしもし.
	P:	Hello.
2	誘:	はい.
	N:	Yes.
3		-0.7
4	歩:	なんか字↑が(0.5)字↑が重なっててど↑こ，(0.8)道がよくわからないんですけｈどｈ
	P:	Letters are overlapping so where, I can't recognize the route
5		-0.4
6	誘:	ええと(2.8)さっきず：っと真っ直ぐ：↓，南へ行きましたよね？
	N:	Well Do you remember downing a street southward just now?
7	歩:	はい.
	P:	Yes.
8	誘:	そのまま，突き当たった場所には：↓，戻れますか？
	N:	Can you return to the corner at the end of the street?
9		-1.6
10	歩:	え，(2.2)((左右を見回す))わかｈらｈなｈいですhu
	P:	What? ((Look around)) I can't remember that.
11	誘:	ええと↓(1.5)い↑ま，どっち向いてるかわかりますか？
	N:	Well Can you tell me your current direction?
12		-1.8
13	歩:	い↑ま：，((画面を見る))((周囲を見る))ええ↑と(3.0)>いや<わからないでｈす
	P:	Now ((Look at cellphone))((Look around))Um. No I can't.
14		-2.5
15	誘:	ええと，(8.7)川の：，(1.7)川の手前の道を，(1.5)前に川ありますか？
	N:	Let me see. river, the road just before the river, can you see a river in front?
16		-2
17	歩:	ないです
	P:	No.
18		-3
19		((地図が更新される))
		((The map on the cellphone is reloaded))
20	誘:	あ，↑あ！
	N:	Oh, Oh!
21	歩:	あ！，い↑ま
	P:	Oh! Now
22		-4.1
23	歩:	あ，これで，(0.3)大通り，[に，出て
	P:	OK, that is Avenue I'm reaching
24		[ああ真っ直ぐ行ったら大通りに出ますね？
		Yeah, you will reaching an avenue. You see?
25	歩:	はい.
	P:	I see.
26	誘:	はい. (2.0)大通りに出たら左に曲がってください.
	N:	OK, Turn left along the avenue.
27	歩:	え，右，(.)ですか？
	P:	What? Right?
28	誘:	左です.
	N:	Left.
29	歩:	あ(.)左，は[いわかりました.
	P:	Oh ,left. I see.
30		[はい
		OK.

By using voice conversation, the pedestrian can ask the navigator any questions orally and obtain detailed information. Actually, the pedestrians most asked questions about routes in the trial 1.2.

3.4.2 The Failure Case of Verbal Navigation and Cause

Most questions observed in experiment 1.2 were the ones about route selection. In every case the navigator tried to guide the pedestrian vocally. But in some cases their verbal communication failed and the navigator could not guide the pedestrian to proper route.

In the following, we discuss the failure case of verbal navigation and the cause of that.

Table 3.1 shows an example of failed navigation where the navigator could not recognize the condition of the pedestrian.

In that case, the pedestrian talks to the navigator that she cannot read the map. In response the navigator tries asking some questions to the pedestrian to know the situation around pedestrian (see line 6,8,11). But at that time the pedestrian is unaware of her location and direction (line 10,13) and he fails to get proper answers. Finally the pedestrian recognize herself approaching an avenue after reloading map (line 23). And whereby the navigator come to know the situation and succeeds to tell the proper route (line 26).

The map on the cellphone is reloaded every one minute and the location measurement and server access takes about 15 seconds with the system. Therefore the map is updated every 75 seconds if the pedestrian takes no action and the pedestrian keeps moving during the time. Additionally there sometimes exist errors in the location measurements by GPS. Therefore in many cases there are large gaps between the current location shown on the map and the actual location. To resolve the gaps, the navigator have to ask some questions to the pedestrian about their condition at first.

In such cases where the pedestrian is lost and ask navigator for guidance, it is difficult for the navigator to get out actual information from pedestrian itself. The similar example is shown in table 3.2.

Table 3.2 : Failure of Navigation Caused by Obscurity of Pedestrian’s Situation #2

1		((歩行者が出発直後に立ち止まり，誘導者に道を尋ねる))
		((Pedestrian stops just after departure and ask the route to navigator))
2	歩：	もしｈもし？
	P:	Hello
3	誘：	はい.
	N:	Yes.
4	歩：	>これ<ってどっ↑ちに，(0.5)曲がったらいいんですか始め，公園出て，
	P:	Which direction should I turn at first, leaving the park.
5		(-1.6)
6	誘：	ええと：，(2.1)真っ直ぐ南に抜けるみち：は(.)ありますか？
	N:	Well, Can you see a road heading southward straight ?
7	歩：	((歩き出す))南，((周囲を見回す))((進行方向を変更))
	P:	((starts walking))Southward,((look around))((turn back))
8	歩：	(4.2)ああ，(2.7)((画面を見る))多分 huh huh huh
	P:	Well, maybe.
9		(-0.6)
10	誘：	あｈ，(1.2)わかりにくいですかね：.
	N:	Well, hard to find ?
11	歩：	はい. (1.2)方角がｈどっちかｈわからないですけどｈ
	P:	Yes. I can't grasp the direction.
12		(-0.4)
13	誘：	ああ：
	N:	Well.
14		(-0.9)
15	歩：	あ今適当に(0.9)あるい，(.)歩き出しました.
	P:	Oh, now I started walking randomly.
16	誘：	はい. (0.6)ええと：，画面に：移動履歴が出るので：，
	N:	OK, well, the movement locus will appear on the screen
17	歩：	はい
	P:	Oh,
18	誘：	それ[で(今)の方向が
	N:	With that, the (current) direction
19	歩：	[ああ はい
	P:	Oh I see.
20	誘：	わかるかと思うんですけど，
	N:	will be available
21	歩：	はい.
	P:	OK

In the example on table 3.2 the pedestrian asks the navigator about route selection (see line 4). Just like the case on table 3.1, the navigator cannot check the pedestrian's condition and fails to navigate her (line 6-13). The navigator

Table 3.3 : Verbal Navigation based on pedestrian's direction

1	歩：	もしもし.
	P:	Hello.
2	誘：	はい.
	N:	Yes.
3		(-0.9)
4	歩：	これって，行き過ぎてますか？曲がるところ，
	P:	Did I pass over the corner to turn ?
5	誘：	え[え：：と
	N:	Let me see.
6	歩：	[>もちょっと<前で(.)曲がったほうが[よかったです(か？)
	P:	Should I turn slightly behind?
7	誘：	[そうです，先ほどの(.)交差点が
	N:	Yes, at the previous cross point
8	誘：	[あったと思うんですけど↑も
	N:	Do you remember?
9	歩：	((立ち止まる))[あ：：
	P:	((stop walking))Oh,
10	歩：	((進行方向を変更))こう-え-交差点>のところ<ですか？
	P:	((turn back)) cross, oh, cross point?
11		(-0.8)
12	誘：	はい，え-先ほどの，(0.5)ええと，(1.9)すぐ，
	N:	Yes. Ah, just now, well, just,
13	誘：	(0.8)ええ：と今，(1.0)今交差点あります？
	N:	Let see oh now, can you see a cross point now?
14	歩：	((周囲を見回す))今こうさてん：，((後方を見る))(2.0)
	P:	((look around)) now, cross point, ((see backward))
15	誘：	細い道[だと思うんですけど
	N:	Narrow road, I suppose.
16	歩：	[ないです↑ね↓. え，戻った方がいいですか？
	P:	No, I can't. Oh, should I turn back?
17		(-0.6)
18	誘：	あ，ええ[：そうですね，[戻ってください
	N:	Well, Yes, Turn back.
19	歩：	[あ [と，
	P:	Oh, Oh,
20	歩：	けっこう，(.)通り過ぎてますよね？
	P:	Did I pass over the for long.
21	誘：	そうですね，はい.
	N:	Yes, that's right.
22	歩：	は：い，わかりました.
	P:	OK, I see.

ends the conversation with an instruction to check the direction using movement locus. The conversation was started with a request for route guidance so the navigator cannot meet the pedestrian's need in the case.

At that time, the map on the cellphone shows an instruction to go southward. But as the pedestrian says "I started walking randomly"(line 15), she lose sense of direction and wrongly starts going eastward. Also in this case the navigation fails due to the impossibility for the navigator to check the pedestrian's condition.

3.4.3 Navigations with Concrete Bases

Table 3.3 shows an example of navigation using movement locus as basis. The pedestrian notices herself having passed the corner to turn by mistake. And then she confirms with the navigator whether she has passed the corner (see line 4,6). In response the navigator answers yes and tries to navigate her to the proper route (line 7 or later).

Like the previous two cases, the navigator asks some questions to the pedestrian and fails to get proper answers in this case(line 12-16). However, the pedestrian tries to navigate her with the words such as "slightly behind", "previous cross point" and the navigation succeeds. These instructions were based on the pedestrian's locus. Therefore she can recognize the proper route despite the lack of direction sense. In the navigation method using voice conversation, it is usual to use pedestrian's locus as basis [3].

Table 3.4 shows an example of information sharing using location information as basis. In the conversation, the pedestrian asks the question "Does this bold black line mean this avenue?"(see line 4). There is an assumption in the question that the navigator sees the same map as hers.

Furthermore the navigator says "Go slightly leftward"(line 14) to the pedestrian. In this conversation, the word "leftward" means not "leftside of the body" but "leftside of the map". So he mean "go westward" with the instruction. The pedestrian recognize this mistakable instruction properly and start heading westward without hesitation.

Unlike the previous examples, it appears that they use the pedestrian's current location instead of movement locus as basis. Such kind of instructions are typical of the navigation method using location information and voice conversation.

Table 3.4 : Verbal Navigation based on Information on Map

1	歩：	((画面を見る))もしもし.
	P:	((look at cellphone))Hello.
2	誘：	はい.
	N:	Yes.
3		-0.7
4	歩：	この黒い太い線てこの大きい(.)通りのことですよね？
	P:	Does this bold black line mean this avenue?
5	誘：	はいそうです.
	N:	Yes.
6		-3.3
7	歩：	((右に曲がる))ええ[(と)
	P:	((turn right))Well,
8	誘：	[真っ直ぐ行くと：↓,
	N:	If you go straight
9		-0.4
10	歩：	はい
	P:	Yes.
11	誘：	>ええと<かさ[いが，火災ですので：↓
	N:	Well, fire disaster, you will face the fire disaster
12	歩：	[火災ですよね？
	P:	Do you mean fire disaster?
13	歩：	はい
	P:	I see.
14	誘：	もうちょっと左に，(.)向かいに行ってください.
	N:	Go slightly leftward.
15	歩：	は：い.
	P:	OK.

In example 1.2 some similar cases were found where the pedestrians use information on maps while asking questions. For example, one of the pedestrians asked the navigator "Can I go along this street?" or "Is this park the destination?".

As described in section 2.1, the navigation based on movement locus sometimes fails due to the difficulty to check the pedestrian's condition. On the other hand, with the navigation using location information, they can use maps as concrete common bases. So misconceptions are not likely to occur as long as the pedestrian can read maps properly. For that reason they frequently used maps as bases of instruction.

We introduced two failure cases in the previous section.

From the opposite point of view, the failure cases we took in the previous section are considered to be caused by the lack of map recognitions. The navigator and pedestrian cannot set common basis if the pedestrian cannot read maps. In cases like that, it is hard for the navigator to guide the pedestrian to the direction intended.

3.4.4 Importance of Assistance on Direction Sense of Pedestrians

It is revealed that the pedestrians need three kinds of information. They are current location, current direction and proper route to the shelter. And it is certain that the pedestrians really want to know the routes out of the three. As shown in section 3.4.2 and 3.4.3, the pedestrians most asked questions about routes in the trial 1.2.

But it is not always true that the navigator can solve the pedestrian's problem. According to the result of previous section, it is necessary for the pedestrian to read the map. Otherwise they cannot receive proper instruction from the navigator.

In addition, there is one more advantage on reading maps. By recognizing maps, the pedestrian get to be able to select proper route in some times. That is to say, recognition of maps is important for the pedestrians to receive support and to act independently.

To read the maps properly, pedestrians must be aware of their current location and direction [7]. About the position, they can receive correct information by reloading maps on GPS-capable phones. However they have no means to receive correct direction with the navigation method. In some situations they can grasp current direction by movement locus. But in the situations such as right after departure or turning corner, they cannot use movement locus properly.

Chapter 4 Research on the Effect of Assistance on Direction Sense

From the result of previous experiment, we drew a conclusion that the navigation fails when the pedestrian cannot read maps properly. And the pedestrians have no means to receive correct direction with the navigation method using location information and voice conversation. The lack of direction sense supposed to be the cause of failure in navigation.

Based on the result, we conducted another experiment to research the effect of assistance on direction sense. In this chapter we describe the settings and the result of the experiment.

4.1 Purpose of Experiment

We considered that the pedestrians can read the maps properly with the assistance on direction sense. And we expected two effects below.

- With the means to check the direction, the pedestrians will make less mischoice on routing.
- With the means to check the direction, the pedestrians become confident and their senses of security will be improved.

In this experiment we conducted two trials. In one trial pedestrians used navigation systems with maps and voice conversation. And in the other trial pedestrians used a compass in addition to maps and voice conversation. We measured the moving distance and senses of security of the pedestrians and compared the results in the two trials.

4.2 Experimental environment

The setting of experimental environment is described below.

4.2.1 experiment description

The subjects participated in this experiment as pedestrians and they performed two trials. We prepared a scenario that huge earthquake had struck Kyoto city. And we provided an explanation to the subjects that the theme of the experiment is evacuation drill. In both trial they left the start point alone

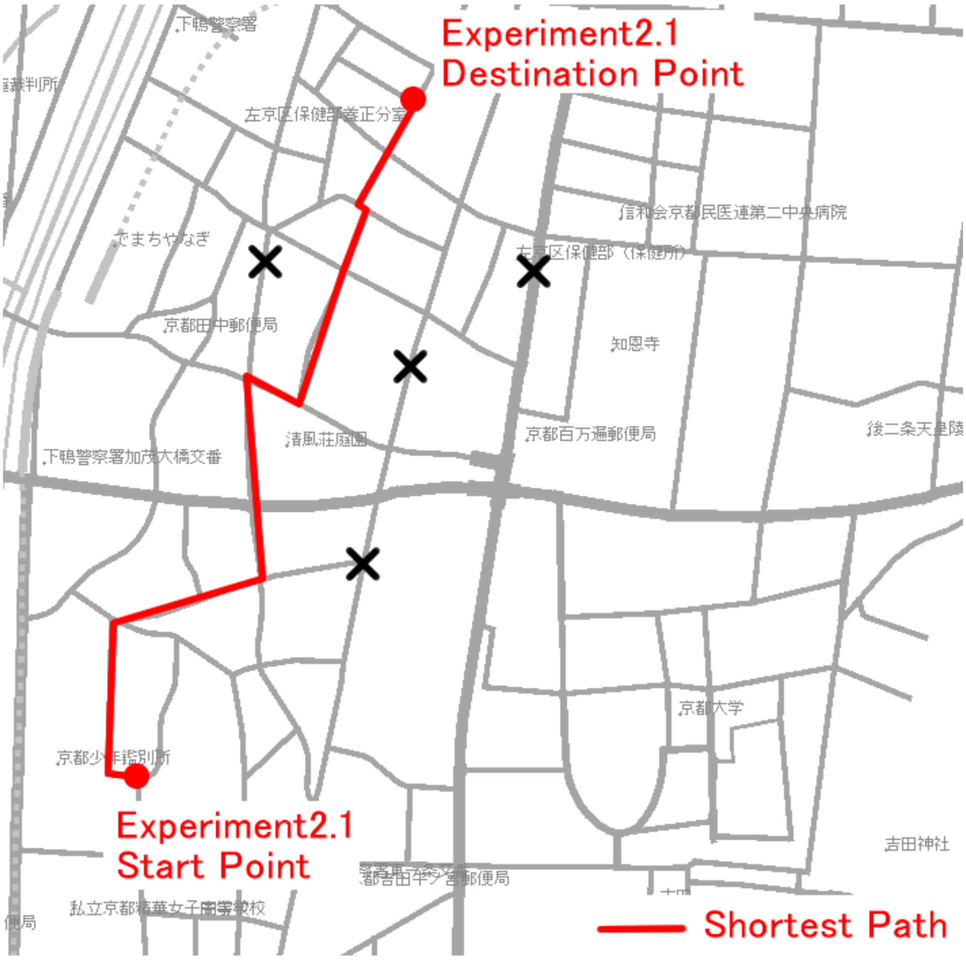

Figure 4.1 : Testing Area of Trial 2.1

and headed for the destination point predetermined. The airline distance from the start to goal is about 1.5 km.

In the following, the subjects are described as pedestrians. We imposed two trials on them with the navigation methods below.

1. The navigation method using maps and voice conversation
2. The navigation method using maps, voice conversation and compass.

We measured their moving distances, the numbers of times to use compass, and the senses of security with the two methods. We describe the measuring method in section 4.2.3.

4.2.2 Task of pedestrians in experiment

Figure 4.1 and figure 4.2 show the maps of testing area on the two trials. The trial on the area of figure 4.1 is described as trial 2.1 below. And the trial on the

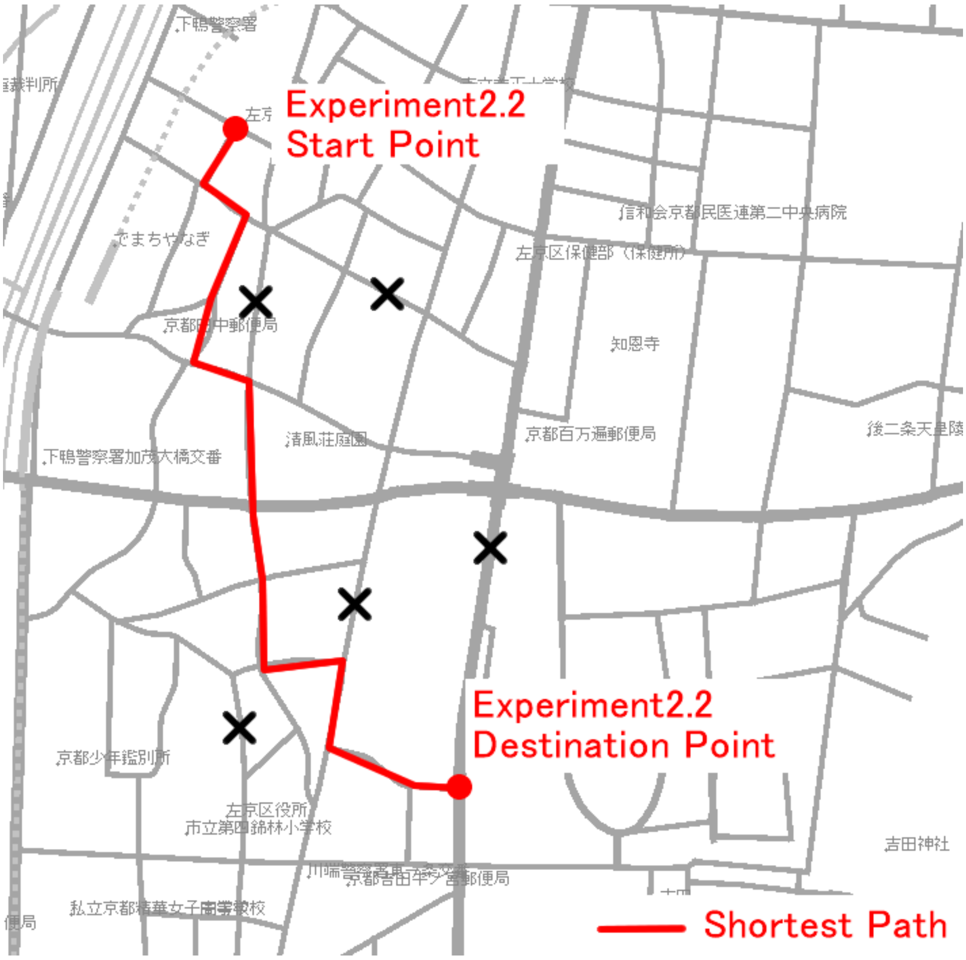

Figure 4.2 : Testing Area of Trial 2.2

area of figure 4.2 is described as trial 2.2.

The pedestrians left the start points on the maps and headed for the destination point using navigation system and compasses. The trial in which compass is available varies by the pedestrian. Half of pedestrians used compass in trial 2.1 and the others used ones in trial 2.2. We gave no instructions about route selection before the trials. Therefore the pedestrians selected routes of their choices.

We set virtual disasters on the points marked X on the maps. We indicated the pedestrians that secondary disasters would happen in some points and they must avoid them.

We also instructed the pedestrians to select shortest route to the destination. By giving the instruction, we can measure the adequacy of pedestrians' route selections as moving distances. That is to say, the pedestrian with adequate route selection takes short distance walk. Conversely, improper route selections present as long moving distances.

We made some features of the two trials even. The distances of the shortest path in the trial 2.1 and 2.2 are equally 1030 meters. Furthermore the both of the paths have 11 cross points and the pedestrians have to turn at 6 of them. By doing this we can resolve the difference of test areas.

As in the case of previous experiment, the commander gave brief instruction on the navigation system. And the navigator responded to pedestrians' questions.

4.2.3 Instructions for Pedestrian

For the pedestrians to utilize the information provided, we instructed them three items below beforehand.

- The summary of the experiment and tasks
- Usage of navigation maps
- Usage of compass

After the instruction we additionally gave the instructions below.

- The theme of this experiment is evacuation drill. So the pedestrians are expected to reach destination points with the shortest routes.
- The pedestrians are allowed to use maps, voice conversation, and compass as information sources. To select the shortest route, pedestrians must use them efficiently.
- The pedestrians are allowed to use only the information sources provided. It is forbidden to ask passing strangers for route information. And it is also forbidden to read neighborhood maps put on the roadside.
- The navigator never speaks to the pedestrians voluntarily. The pedestrians are expected to ask the navigator for information whenever in need of help.
- The pedestrians can receive current location by reloading maps whenever in need.

Table 4.1 Order of Tasks

	Trial 2.1	Trial 2.2
Even-Numbered Pedestrian	With Compass	Without Compass
Odd-Numbered Pedestrian	Without Compass	With Compass

4.2.4 Factors to Affect the Result of Experiment

The purpose of this experiment is to research the effect of assistance on direction sense. However the factors listed below also affect the result.

- The difference in testing areas
- The order of two tasks (task with compass and without compass)

We made the features of two testing area even to resolve the former. Moreover, we analyzed the ratio of moving distance to the sample average instead of analyzing moving distance itself.

And to resolve the latter, we blocked the order of tasks and testing areas as shown in table 4.1.

4.2.5 Data Acquisition Environment

In this section, the method to acquire data for analysis is described.

Figure 4.3 shows the data acquisition environment in the experiment.

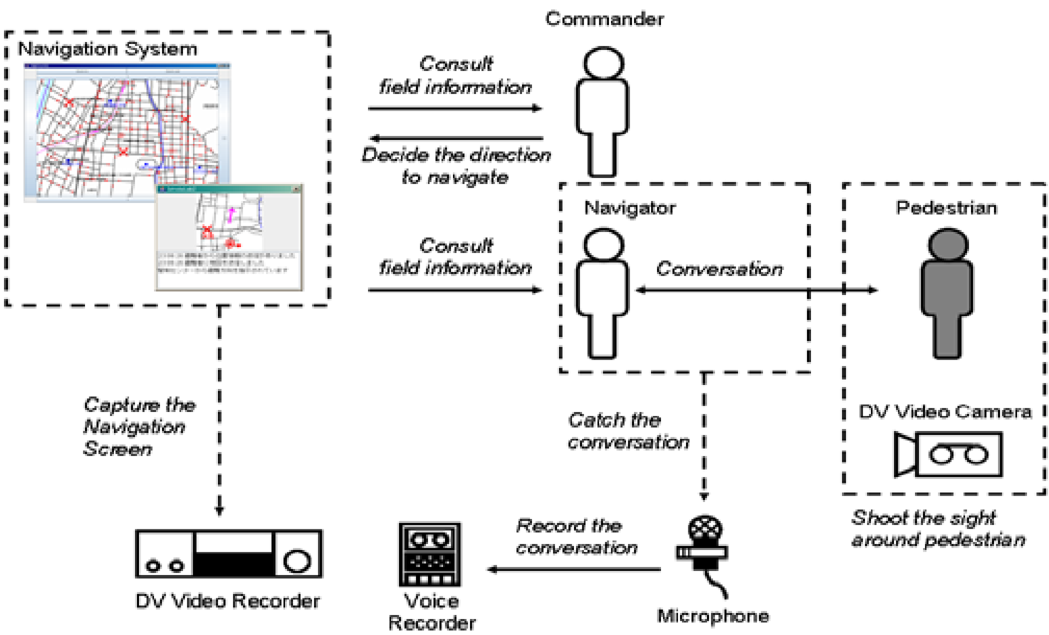

Figure 4.3 : Data Acquisition Environment of Trial 2.1 and 2.2

Table 4.2 : Questionnaire to Ask Sense of Direction(SDQ-S)

1.　知らない土地へ行くと，とたんに東西南北がわからなくなる．
（はい）１　・　２　・　３　・　４　・　５（いいえ）（以下同様の５段階）
*2.　知らないところでも東西南北をあまり間違えない．
3.　道順を教えてもらうとき「左，右」で指示してもらうとわかるが「東西南北」で指示されるとわからない．
4.　電車（列車）の進行方向を東西南北で理解することが困難.
5.　知らないところでは自分の歩く方向に自信が持てず不安になる．
6.　ホテルや旅館の部屋にはいるとその部屋がどちら向きかわからない．
7.　事前に地図を調べていても初めての場所へいくことはかなり難しい．
*8.　地図上で自分のいる位置をすぐに見つけることができる．
*9.　頭のなかに地図のイメージをいきいきと思い浮かべることができる．
10. 所々の目印を記憶する力がない．
11. 目印となるものを見つけられない．
12. 何度も行ったことのあるところでも目印になるものをよく覚えていない．
13. 景色の違いを区別して覚えることができない．
14. 特に車で右折左折を繰り返して目的地に着いたとき，帰り道はどこでどう曲がったらよいかわからなくなる．
15. 自分がどちらに曲がってきたかを忘れる．
16. 道を曲がるところでも目印を確認したりしない．
17. 人に言葉で詳しく教えてもらっても道を正しくたどれないことが多い．
18. 住宅地で同じような家が並んでいると目的の家がわからなくなる．
*19. 見かけのよく似た道路でもその違いをすぐに区別することができる．
20.　２人以上であると人についていって疑わない．
(設問前の*は逆転項目を表す)

Moving distance of pedestrians

We recorded the pedestrians' location data sent to the system. Additionally, the pedestrians took video cameras during the trials and shot the sight around their routes. We used these two data to measure the pedestrians' moving distance.

We determined detailed movement locus of pedestrians from the location data and the footages of the video data. And next we split the locus into small sections by each cross points. Furthermore we measured the length of each sections by using distance calculation service on the Web[1]. Finally, we summed the length of all sections on the locus and defined it as moving distance.

With the procedure above, we can resolve measuring errors of distances. By defining the length of each sections first, the pedestrians selecting the same

[1] キョリ測： http://www.mapion.co.jp/route/

routes are handled with the same values of distance.

Pedestrian's self evaluation of direction sense

We sent out the questionnaires before the experiment to ask pedestrians' self evaluations of direction sense. Table 4.2 shows the contents of it.

The questionnaire is called SDQ-S[15]. The sum of the scores on each question indicates answerer's self evaluation of direction sense. In each question answerer makes one choice among 1(yes) to 5(no). Therefore every answerer obtains a score within 20 to 100.

Pedestrian's sense of security during walking

We sent out the questionnaires after each trials. The questionnaire was designed to measure the pedestrians' sense of security during walking. We also asked availability and reliability of the system, and some other questions to hide the intention from answerer. Table 4.3 shows the contents of the questionnaires. In each questions answerer makes one choice among 1(I disagree) to 9(I agree). The question 10, 11 and 12 ask pedestrians their sense of security. In the actual questionnaire, we sorted all the questions randomly.

Frequency and situation where pedestrians used compass

We also prepared questions to ask the frequency and situation where pedestrians used compass.

They are shown as the latter two questions in table 4.3.

To collect exact answers, we told the existence of these two questions to the pedestrians before the trials.

4.3 Experimental results

We conducted the experiment described in the previous section and collected the data of 10 pedestrians. The results of the experiment is described in the followings.

Table 4.4 shows the answers of the questionnaire and the moving distances of each pedestrian.

The item "sense of direction" means the score of SDS-Q questionnaire introduced in section 4.2.5. It represents the pedestrian's self evaluation of direction sense. The highest score was 73 and lowest score was 25. And average

Table : 4.3 Questionnaire to Ask Sense of Security

1(2)回目の避難で利用した誘導情報(地図・会話・コンパス)について以下の設問にお答えください.

1. 使い易かったですか？
全く使い易くなかった 1 2 3 4 5 6 7 8 9 とても使い易かった
2. 移動中に不安を感じましたか？
全く不安を感じなかった 1 2 3 4 5 6 7 8 9 とても不安を感じた
3. 誘導は信頼できましたか？
全く信頼できなかった 1 2 3 4 5 6 7 8 9 とても信頼できた
4. 誘導情報には説得力がありましたか？
全く説得力がなかった 1 2 3 4 5 6 7 8 9 とても説得力があった
5. 技術的に高度であると感じましたか？
全く高度とは感じなかった 1 2 3 4 5 6 7 8 9 とても高度だと感じた
6. 避難の訓練になりましたか？
全く訓練にならなかった 1 2 3 4 5 6 7 8 9 とても訓練になった
7. 提供された誘導情報は十分でしたか？
全く十分でなかった 1 2 3 4 5 6 7 8 9 とても十分だった
8. 誘導に従う気になりましたか？
全く従う気にならなかった 1 2 3 4 5 6 7 8 9 とても従う気になった
9. 実用化されたら使ってみたいと思いますか？
全く使いたいと思わない 1 2 3 4 5 6 7 8 9 とても使いたいと思う
10. 自信を持って行動できましたか？
全く自信を持てなかった 1 2 3 4 5 6 7 8 9 とても自信を持てた
11. 誘導情報は役に立ちましたか？
全く役に立たなかった 1 2 3 4 5 6 7 8 9 とても役に立った
12. 落ち着いて移動できましたか？
全く落ち着いてできなかった 1 2 3 4 5 6 7 8 9 とても落ち着いてできた

(以下はコンパスを持って避難を行った場合のみ解答してください)

移動中にコンパスを何回利用しましたか？ 回

どのような時にコンパスを使いましたか？ご自由にお書きください.

score was 55.4. We examined the correlation between the score and other parameters like moving distance or frequency of using compass. In the result we found no strong correlation there.

The item "trial" means the number of trial from which the data was collected. For example, the data whose number of "trial" is "1" means that the data were collected from trial 2.1.

Table 4.4 : Results of Questionnaire and Moving Distances

		With Compass						Without Compass				
Pedes trian No.	Sense of dire ction	trial	Frequ ency	Secu rity	Avail abili ty	Reli ability	Dist ance	trial	Secu rity	Avail abili ty	Reli ability	Dist ance
1	73	1	0	22	25	24	1040	2	25	25	23	1255
2	45	1	2	25	25	26	1021	2	26	27	27	1271
3	55	2	1	18	17	21	1255	1	7	13	6	1235
4	69	2	1	24	24	22	1154	1	20	24	24	1040
5	25	1	0	23	26	22	1084	2	25	25	22	1391
6	60	1	0	15	25	24	1223	2	18	25	24	1436
7	52	2	4	9	22	15	-	1	8	23	16	2374
8	42	2	2	22	19	20	1490	1	8	26	20	1350
9	63	1	1	25	27	25	1084	2	24	25	23	1231
10	70	2	2	17	26	24	1414	1	12	17	16	1141
Ave.	55.4		1.3	20.0	23.6	22.3	1196		17.3	23.0	20.1	1372

The item "frequency" means the number of times the pedestrian used compass in the trial. We collected the data from the questionnaire after each trial.

The items "security", "availability" and "reliability" means the pedestrians' evaluation about the system. These scores were measured with the questionnaire after each trial. Each item are sum of three questions showed in table 4.3. Therefore every score keeps within 3 to 27.

We examined Cronbach's coefficient alpha of the three questions about security sense. The coefficient was 0.93 in the trial with compass, and 0.87 in the trial without compass. They are sufficiently high values so the results of questionnaire are reliable enough.

The item "distance" means the pedestrian's moving distance from start to destination in each trial. We described that the distance of shortest route in a trial is 1030 meters. But according to the table, pedestrian-2's moving distance in trial with compass is less than 1030 meter. That is because pedestrian-2 found uncharted shortcut in the trial.

There was a malfunction of experimental device with pedestrian-7 in trial

2.2. And we stopped the trial halfway and sent out the questionnaire at the time. Therefore the data about pedestrian-7 are incomplete. For the reason, we did not use these data for analysis.

4.4 Analysis and discussion of result

The detailed result of analysis and discussion are described in the following.

4.4.1 Effect of direction assistance on pedestrian's direction sense

We researched the effect of assistance on pedestrian's direction sense.

The six of nine pedestrians actually used compass in the trials with ones.

We compared the pedestrians' senses of security in the trials with compasses and without ones. As shown in the table 4.4, there exists improvement tendency with the use of compass. The average score of all six pedestrians is arisen from 16.2 to 21.8. Especially, pedestrian-3's score is elevated from 7 to 18 with the use of compass.

We inspected actual movement locus of pedestrian-3 in the two trials. Then we found that he had made one oversight of corner and one mischoice of route in the trial without compass. On the other hand, he had made no mistakes in the trial with compass. In this case, the effect of compass is shown obviously.

These results show that the assistance on pedestrians' senses of direction has improvement effect on their senses of security.

4.4.2 Effect of direction assistance on pedestrian's moving distance

We researched the effect of direction assistance on pedestrian's moving distance next.

We calculated the ratio between moving distances of each pedestrian in trial 2.1 and average distances of all. Next we also calculated the ratio with the moving distances in trial 2.2. These ratios are shown in "ratio - trial2.1" and "ratio - trial2.2" on table 4.5.

These ratios are sorted by the use of compass in the column "ratio - with compass" and "ratio - without compass" on the table.

Each of the ratios represents the adequacy of each pedestrian's route selection relative to others. Therefore the lower ratio means better route

Table 4.5 : Ratio of moving Distance

Pedes trian No.	Distance 2.1	Distance 2.2	Ratio trial2.1	Ratio trial2.2	Ratio with compass	Ratio without compass
1	1040	1255	0.916	0.949	0.916	0.949
2	1021	1271	0.899	0.962	0.899	0.962
3	1235	1255	1.088	0.949	0.949	1.088
4	1040	1154	0.916	0.873	0.873	0.916
5	1084	1391	0.955	1.052	0.955	1.052
6	1223	1436	1.077	1.086	1.077	1.086
8	1350	1490	1.189	1.127	1.127	1.189
9	1084	1231	0.955	0.931	0.955	0.931
10	1141	1414	1.005	1.070	1.070	1.005
Ave.	1135.3	1321.9			0.980	1.020

selection.

The average ratio of all six pedestrians is slightly lowered from 1.02 to 0.98. Compared with the case of moving distance, the difference is quite small and the effect of compass is uncertain.

4.4.3 Situation where pedestrians use compass

In the previous section, we found only a small effect of direction assistance in pedestrian's moving distance.

According to the result of questionnaire in table 4.4, the pedestrians used compasses only a few times. There is a possibility that the right effect of direction assistance did not appear due to inadequate uses of compasses.

To confirm whether the pedestrians used compass properly, we compared the pedestrians'' movement loci with their usage of compasses.

As a result, we found some mischoice of routes with inadequate uses of compass.

Figure 4.4 shows the mischoice of route pedestrian-6 made in trial 2.1. He turned to the wrong direction at the corner surrounded by the dotted frame. It is conceivable that he could select correct route by using compass at the corner. In the questionnaire he answered he had never used the compass in the trial. This means that he could not use the compass adequately.

We can see the result as follows. With a compass the pedestrian can check the current direction and fix his route whenever he wants. However if he does not recognize the necessity to check the direction at proper time, he never use the compass and the wrong route is never fixed. In the case mentioned, pedestrian-6 seems not to have recognized the necessity to check the direction. The compass never works well in the cases like that.

Figure 4.5 shows the mischoice of route pedestrian-8 made just after the start in trial 2.2. This example differs from the previous one in the way following. He answered in the questionnaire that he had checked the direction at that time. Despite the check of direction, he started walking toward the wrong direction and took the long way as a result.

All the participants of the experiment were told about the usage of compass. Therefore pedestrian-8 could have recognized the direction properly with compass. Considering these facts, it seems that he could not match up the the

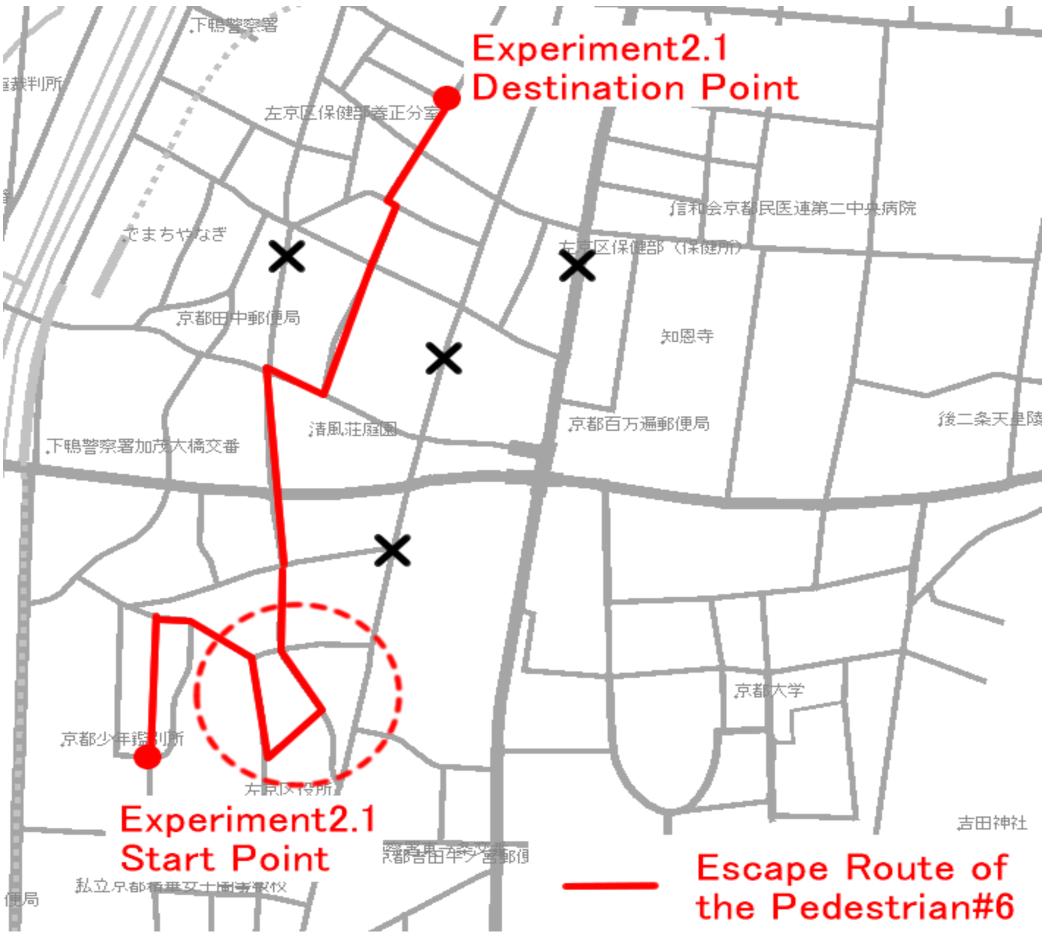

Figure 4.4 :Mischoice of Route #1

direction in real space and the map correctly. At the time he walks toward wrong direction being unaware of that. The compass never works well either in such cases.

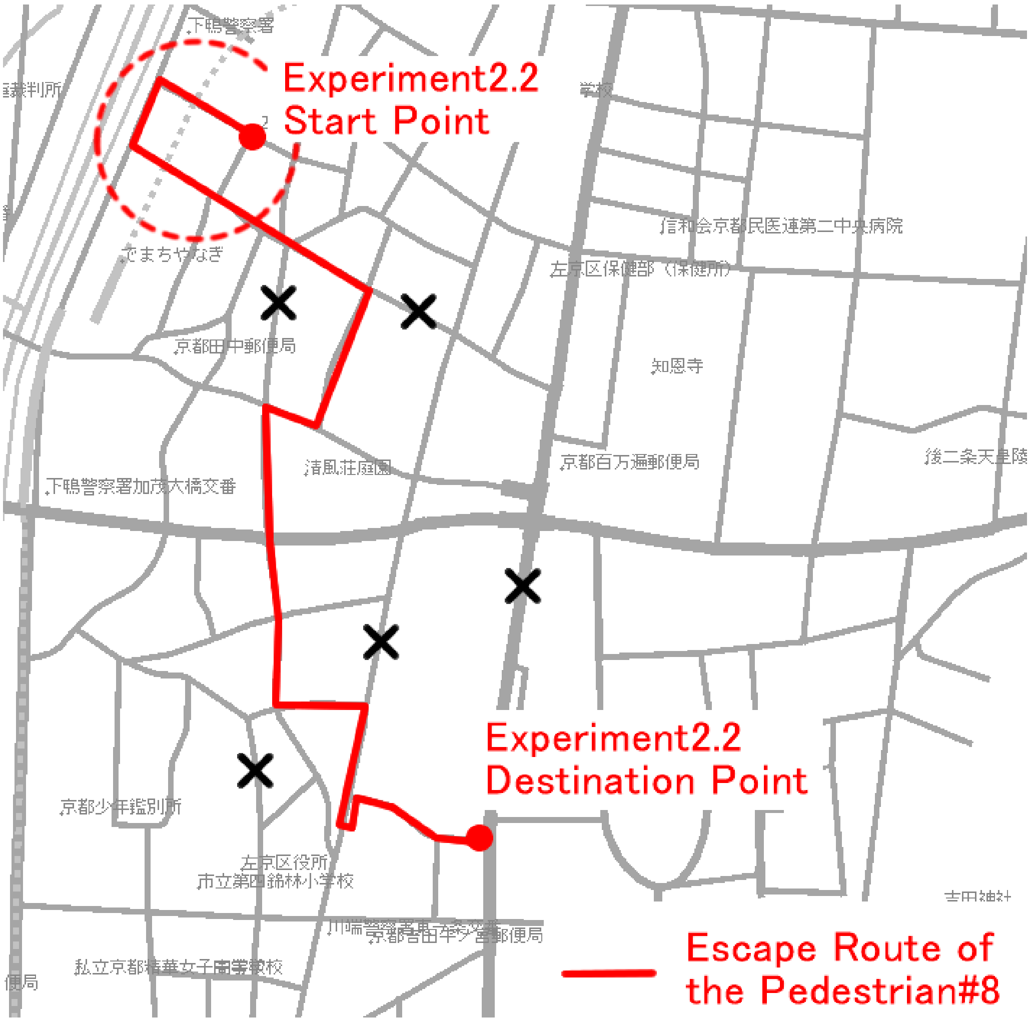

Figure 4.5 : Mischoice of Route #2

Chapter 5 Discussion

In chapter 3, we researched the communication on the navigation method using location information and voice conversation. With the method the navigator and pedestrian can use maps as concrete bases of verbal navigation. Such kinds of navigation have advantages below.

- It is difficult to guide the pedestrians who are bad at reading maps with the method using only location information. But the pedestrians can gain any information they want by using voice conversation in parallel.
- The navigation method using only voice conversation also has a problem. The navigator and the pedestrian have difficulty in setting a basis for guidance. That causes misguidance in the navigation. By using location information in parallel, they can use the information on the map as concrete bases. Therefore communication between the navigator and the pedestrian goes on smoothly.

Though it is also found that adequate recognition of the map is necessary for the pedestrian to receive smooth verbal guidance from the navigator. In the cases where the pedestrian cannot read the map properly, verbal guidance often failed. That is because the navigator cannot recognize pedestrian's position and direction adequately.

With the navigation system using GPS-capable cellphones, the pedestrians can check their current location anytime they wish. But there are no means to check the current direction, which is one of the two information they need to read maps adequately.

In the experiment described in chapter 4, we researched the effect of direction assistance in navigation. Then we confirmed that pedestrian's sense of security was improved with the use of compass. However, we also found some pedestrians who made mistakes in route selection. They make mischoice due to the unawareness of necessity to check direction or inability to use compass adequately.

We have to give the pedestrians some means to help their recognition about location and direction. However, it seems not enough just to prepare the means to check the information.

In the experiment described in chapter 3, we saw a pedestrian who kept going on a wrong route. That is because she did not notice herself misunderstanding the route so she never checked the maps. Furthermore in the experiment of chapter 4, we found pedestrians who took wrong routes. That was due to the unawareness of necessity to check directions.

By the results above, it is desirable for the navigation system to indicate the necessity of checking conditions to the pedestrians. Recently, cellphones with electronic compasses are spreading. With the electronic compass, the system can manage pedestrian's direction autonomously. By doing that, it becomes possible that the system instructs the pedestrian to check the direction when necessary.

The pedestrian who truly need the verbal navigation are ones who are bad at reading maps. With the mechanics described above, we can support the map recognitions of such pedestrians who have tendency to get lost. And with the proper map recognition, the pedestrian can receive smooth verbal navigation from the navigator.

Chapter 6 Conclusion

In this study, we researched communication on the navigation system using location information and voice conversation. The object of research is to reveal the merit and problem of the navigation method. Therefore we re-created navigation system with the method and conducted two experiments below.

Comparative Experiment with Existing Navigation System We compared two pedestrian navigation systems. One uses only maps generated by location information. And the other uses voice conversation with navigator at the same time. In this experiment, we analyzed the subjects' behaviors and conversations to reveal what kind of information pedestrians need and how the information is provided. To observe the information needed, we applied an experimental maneuver letting two subjects act together and observed the conversations between them.

Comparative Experiment to Research the Effect of Direction Assistance We drew a following hypothesis from the first experiment - "With an assistance of direction sense, pedestrians get to read the maps adequately, and that leads effective use of voice conversation". To confirm the hypothesis, we introduced direction assistance to the navigation system and performed an experiment to investigate the effect.

The contribution of this study is as follows.

Clarification of the Merit and Problem on the Navigation Using Location Information and Voice Conversation We found that pedestrians and navigators often use maps as a basis of verbal navigation through voice conversation. We also found that in the cases where pedestrian do not understand maps adequately, navigation sometimes fails due to the lack of basis.

Clarification of the effect of Direction Assistance We confirmed that some pedestrians feel more secure with the use of compass. We also confirmed that it is not enough just to offer the way to check the direction. In some case, the pedestrian cannot recognize the timing to check the direction and gets lost.

The conclusion is that, when we use a navigation system using location information and voice conversation, it is desirable to assist pedestrian's sense of direction at the same time.

To assist the direction sense, electronic compasses are available recently. With the electronic compass, the system can manage pedestrian's direction autonomously. By doing that, it becomes possible that the system instructs the pedestrian to check the direction when necessary.

The pedestrian who truly need the verbal navigation are ones who are bad at reading maps. With the mechanics described above, we can support the map recognitions of such pedestrians who have tendency to get lost. And with the proper map recognition, the pedestrian can receive smooth verbal navigation from the navigator.

Acknowledgments

The author would like to express sincere gratitude to the supervisor, Professor Toru Ishida at Kyoto University, for his continuous guidance, valuable advice, and helpful discussions.

The author would like to express his thanks to the advisers, Professor Hirokazu Tatano at Kyoto University, Assistant Professor Kunihiko Numata at Kyoto University, Assistant Professor Shigeo Matsubara at Kyoto University, Lecturer Tomohiro Kuroda at Kyoto University, and Research Fellow Katsuya Takanashi at Kyoto University.

The author would like to express his thanks to Mr. Yuu Nakajima at Kyoto University, for his valuable advice, and technical support.

This research has been supported by Collaboration Leadership Training Program (proposal track, 2006.4-2007.2) from Initiatives for Attractive Education in Graduate Schools "Collaborative Design of Information Systems through Interaction with Society".

参考文献

[1] T.Suzuki, S.Okazaki：”Way-Finding Behavior with Verbal Communication in a Virtual Maze”, Journal of Architecture, Planning and Environmental Engineering (Transaction of AIJ), 543, pp.155-162, (2001). (in Japanese)

[2] H.Nojima, N.Shingaki: “How to tell a route: Information transmission with a mobile phone”, IPSJ HI-79, (1998). (in Japanese)

[3] 山崎敬一：“モバイルコミュニケーション 携帯電話の会話分析”，大修館，(2006).

[4] T.Aomi, Y.Tadokoro: “Portable Human Navigation System and Its Evaluation”, IEEJ transactions on electronics, information and systems, vol.122-C, no.12, pp.2083-2090, (2002). (in Japanese)

[5] Y.Nakajima, H.Shiina, S.Yamane, H.Yamaki and T.Ishida: “Disaster Evacuation Guide Using a Massively Multiagent Server and GPS Mobile Phones” IEEE/IPSJ Symposium on Applications and the Internet (SAINT-07), (2007).

[6] T.Aomi, Y.Tadokoro: “Navigation Evaluation for the Human Navigation System” Technical Report of IEICE, ET2001-94, pp.83-90, (2002). (in Japanese)

[7] K.Fujii，S.Azuma，K.Arakawa: “The Influence of Route Guides on Navigation Process”, Transaction of IEICE, Vol.J87-A, No.1, pp.40-49, (2004). (in Japanese)

[8] L.A. Streeter, D.Vitello: “A profile of drivers' map reading abilities”, Human Factors, Vol.28, pp.223-239, (1986).

[9] H.Nakanishi, S.Koizumi, T.Ishida and H.Ito: “Transcendent communication: location-based guidance for large-scale public spaces” CHI ‘04: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 655-662, (2004).

[10] H.Ito, H.Nakanishi, T.Ishida: “An Analysis of Location-based Remote Instructions by Transcendent Communication”. IPSJ Journal. Vol.48, No. 3, (2007). (in Japanese)

[11] N.Shingaki, H.Nojima: “When You Ask for a Route: The Role of Other

People as External Resources in Navigation", JCSS, Vol.5, No.3, pp.49-58, (1998). (in Japanese)

[12] May, A., T. Ross, et al.: "Pedestrian navigation aids: information requirements and design implications." Personal and Ubiquitous Computing 7(6), pp.331-338, (2003).

[13] Ericsson, K., & Simon, H.: "Verbal reports as data" Psychological Review 87 (3), pp. 215-251, (1980).

[14] Nielsen, J.: Usability Engineering. MA.Academic Press, (1993).

[15] Y.Takeuchi: "Sense of Direction Questionnaire", Bulletin of Aichi University of Education, Educational Science, vol.39, pp.127-140, (1990). (in Japanese)