# Trekking Navigation System using Opportunistic Communication

Yasuhiko Kitamura, Shunsuke Nosaka, Hirofumi Kishino and Yui Okuda
*Department of Informatics, Kwansei Gakuin University, Sanda, Hyogo, Japan*

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Abstract: Mountain climbing or trekking becomes popular in Japan recently. Unfortunately the more climbers go to mountains, the more get lost. Handy GPS's are a well-known tool to navigate climbers in the mountain area by displaying their location on a digital map. They are useful to know the current location, but not suitable to call an emergency help. Cell phones are useful to call a help, but they work only in the city area accessible to mobile phone networks. They seldom get access to them in the mountain area. This paper proposes a new trekking navigation system, which consists of mobile terminals and a server, that works even in the poor communication environment where the Internet access is often disrupted such as in the mountain area. The terminals can navigate climbers even when the Internet access is unavailable. When they can get access to the server, they send the walking trajectory of the climbers, so the rescue party can locate the climbers in need. They can also exchange the walking trajectory with each other by utilizing opportunistic communication and carry the information until they reach an area accessible to the server. This paper shows a prototype of trekking navigation system under development and how the opportunistic communication improves the location estimation of climbers.

## 1 INTRODUCTION

A multi-agent system (Weiss, 1999; Wooldridge, 2009) consists of multiple agents that collaborate with each other to solve a problem, and most of research works presuppose the communication environment is stable with a few notable exceptions (Durfee et al., 1987). When the communication environment is not stable, the agents need more intelligence to cope with the delay and/or lost of messages to be transmitted among them. In this paper, we propose a trekking navigation system, which can be viewed as a multi-agent system situated in a poor communication environment, because the communication environment in the mountain area is typically unstable.

Recently the population of Japanese mountain climbers is more than 10 million and a number of climbers get into trouble because of rapid weather changes, going astray, injury, deconditioning, and so on.

Handy GPS's are widely used among climbers as an IT tool to locate them in the mountain. The tool measures the latitude and longitude of the current location by using GPS (Global Positioning System) and displays its location on a digital map. It is useful when a climber needs to know his/her current location but not suitable when he/she needs to inform his/her location to a rescue party.

Recently many of climbers go to mountains with cell phones. They work as a tool to call an emergency help while they can get access to mobile phone networks, but they do not work in the large part of the mountain area because the access to the mobile phone networks is frequently disrupted. Figure 1 shows a cell phone accessibility map along a trekking route in Mt. Mino, Osaka, Japan. The accessibility frequently changes depending on the terrain. In this paper, we call such a communication environment as Poor Communication Environment (PCE) (Fujihara and Miwa, 2010; Vasilakos et al., 2012) where the Internet access is frequently disrupted.

In this paper, we propose a new trekking navigation system, consisting of terminals and a server, that can work in PCE with the following functions.

1. When the terminal is not accessible to the server, it works as a stand alone navigator to inform the current location to the user and records his/her walking trajectory.
2. When the terminal is accessible to the server, it sends the walking trajectory record stored in it to the server.
3. When a terminal encounters another terminal, they exchange their walking trajectory records

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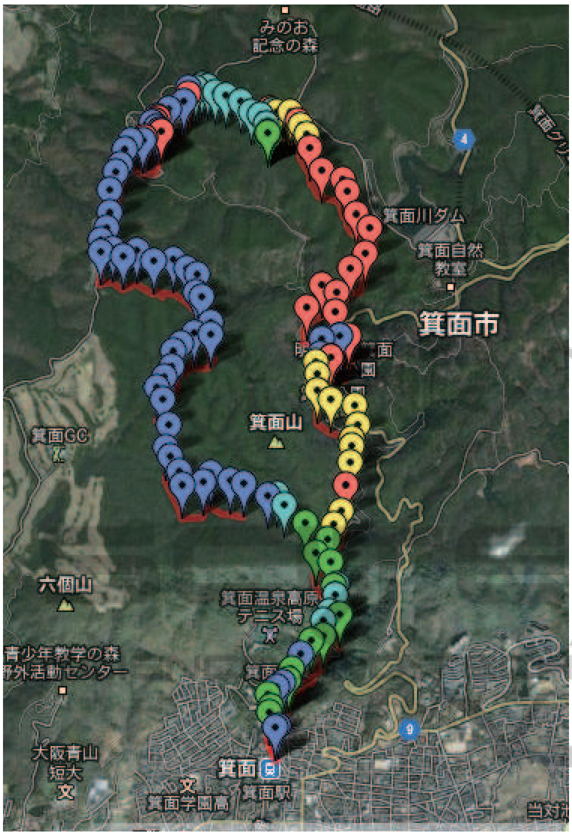


Figure 1: A cell phone accessibility map around Mt. Mino, Osaka, Japan on August 8th, 2012. (Red: inaccessible, Yellow: very weak, Light blue: weak, Green: moderate, and Blue: good).

with each other by using the P2P communication link (Fujihara and Miwa, 2010).

Figure 2 shows how the system works. Terminal A (T_A) in an Internet accessible area sends its walking record to the server. It encounters Terminal B (T_B) in the mountain area where no Internet access is available and exchanges the records with T_B. When T_B reaches an Internet accessible area, it sends its records together with the ones from T_A to the server. If the climber with T_A get lost in the mountain, the rescue party goes to find him/her estimating his/her location by referring to the walking records stored in the server.

In this paper, Section 2 summarizes GPS applications for walkers and Section 3 shows a prototype of our trekking navigation system developed as an Android application and discusses how the estimation of locating a lost climber is improved by using opportunistic communication. Section 4 summarizes this paper with our future work.

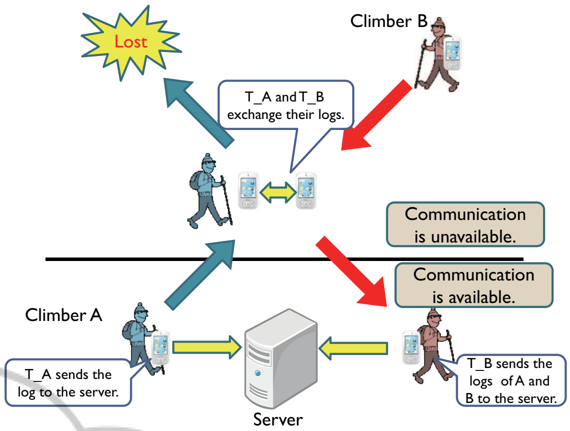


Figure 2: Trekking navigation system in poor communication environment.

## 2 GPS APPLICATIONS FOR WALKERS

Car navigation systems are a well known application using GPS, but it can be applied for human walkers as shown below.

**Handy GPS's.** Garmin[1] has developed handy and battery operated GPS's to inform the current location to the user for outdoor activities like mountain climbing and trekking. The terminal works offline, and digital maps have been installed to show the location on its display without communication. The user can set the destination on the map and the terminal navigates him/her to it. It also shows the walking distance, average speed, barometer, altitude, and so on. The maps can be obsolete and the user requires to update them manually.

**Walking Navigation Systems.** Walking navigation systems are available as an application of cell/smart phone and navigate users to a destination just like car navigation systems. After setting a destination, the system shows routes depending on the transportation such as train/bus, car, or walk. It measures the current location by using GPS, uploads the digital map around the current location through cell phone networks, and displays it on the screen. It navigates the user by using speech synthesis and/or vibrations in a real-time manner. It works online and the maps are automatically updated to be the latest ones. It can collaborate with other services such as shopping, restaurant, and event recommendation systems.

[1] http://www.garmin.co.jp/

**Real-time Locating Service.** Japanese security company Secom has commercialized a real-time locating service to deal with social problems such as kid napping, theft of cars and motorcycles, wandering aged people, and so on. The service utilizes a GPS terminal connected to a server through cell phone networks. The user can locate wandering people with the terminal through the Internet. This service works only online.

Table 1 shows a comparison of GPS applications for walkers. There are differences on how the digital maps are stored on terminals, who are the target users, and the quality of the communication environment.

Handy GPS's are developed for users who enjoy outdoor activities like mountain climbing, trekking, and so on and are supposed to be used offline. The digital maps have been installed manually in advance. Handy GPS's are stand alone systems that do not need communication to the servers.

On the other hand, Walking Navigation Systems suppose good communication environment and always work online. They are normally connected to the servers, and they can download the digital maps in need at any time.

The target users of Real-time Locating Service are not ones who have the GPS terminal but the ones who search for the one with the GPS terminal. The GPS terminal does not have a display to show digital maps. The system works in the good communication environment because communication links between terminals and servers should be stable to know the location of the terminals.

The conventional systems mentioned above are not suitable in PCEDHandy GPS's can inform the current location to the climber but they cannot inform it to the rescue party when the climber gets lost. Walking Navigation Systems and Real-time Locating Service suppose the good communication environment and they cannot work properly in the PCE like the mountain areas. We propose a new walking navigation system that navigates the user as a stand alone system even when the Internet access is unavailable and sends walking records to the server, when the Internet access is available, to inform the location of the climber to the rescue party in need.

It is difficult to estimate the location of the climber when the Internet access is unavailable for a long time. As a remedy, we utilize opportunistic communication based on the P2P access between the terminals. When a terminal encounters another, they exchange the walking records with each other. When the terminal reaches an area where the Internet access is available, it sends not only the walking record of the terminal but also ones of the other terminals that it has encountered. This leads to a better location estimation of the climbers.

## 3 TREKKING NAVIGATION SYSTEM IN PCE

We are developing a new trekking navigation system that works on a smartphone. It works without the Internet access in PCE like the mountain area, because digital maps have been installed in it. It measures the latitude, the longitude, and the altitude of the current location in a constant interval by using GPS and displays the current location on the digital map. It also measures the signal strength of mobile phone networks.

The terminal records the walking trajectory and sends it to the server when the Internet access is available. It exchanges the record with the other terminal through Bluetooth when it encounters the other terminals. When the climber with the terminal gets lost, the rescue party gets access to the server to estimate the location of the climber referring to the walking record.

We performed a simulation experiment to show how opportunistic communication improve the traceability of climbers. We model walking routes as a grid world shown in Figure 3. Climbers repeat to walk between S and G at a constant speed. It takes 200 steps to go to G and to return to S. When a climber reaches a branch, he/she takes a route closer to the destination. If there is a tie between two routes, he/she chooses one at random. We record the history of encounters among climbers and calculate the traceability of climbers depending on the number of climbers in the area. Figure 4 shows a result of the simulation. X-axis shows the location on route and Y-axis shows the estimation of the location. Climbers start from S(0%), go to G(50%), and return to S(100%). "Ideal" means the estimation when the Internet access is always available, and it is correct at every location on the route. When we assume the Internet access is available only at S, the estimation becomes incorrect except at S. The difference becomes large when the number of climbers is few.

## 4 SUMMARY AND FUTURE WORK

We proposed a new trekking navigation system that works even in the poor communication environment where communication links are frequently disrupted.

Table 1: Comparison of GPS applications for walkers.

| | Handy GPS | Walking Navigation Systems | Real-time Locating Service |
|---|---|---|---|
| Digital maps on terminal | Manually stored | Downloaded | None |
| Users | Terminal holders | Terminal holders | Searchers |
| Communication environment | Bad | Good | Good |

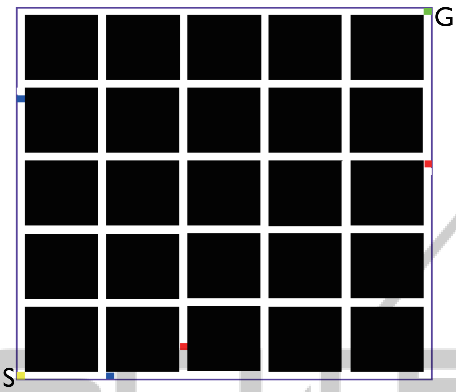


Figure 3: The simulation model of walking routes.

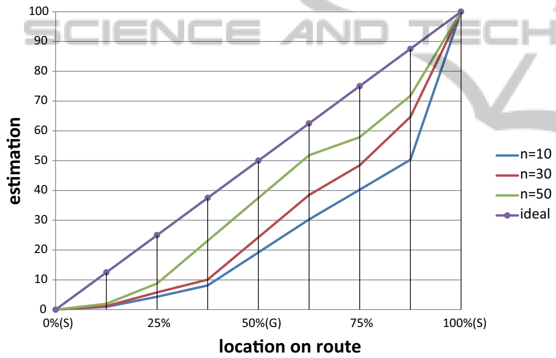


Figure 4: Result of simulation.

When the communication link is unavailable, the system navigate the user by using GPS and digital maps as a stand alone system and records the walking trajectory in the terminal. When the terminal gets access to communication networks, it sends the record to the server. If the user gets lost, the rescue party can estimate his/her location referring to the record stored in the server. We show that the estimation is improved by using opportunistic communication among the terminals.

We have already developed a prototype system with the navigation function as an Android application and plan to install the communication function to the server and the P2P communication function through Bluetooth. We have showed that how opportunistic communication improve the location estimation by using an schematic example, but we need to further evaluate the effect changing parameters such as the complexity of mountain routes, the frequency of encounters among climbers, the signal strength in the mountain, and so on.

From a view of the terminal autonomy, how to conserve the battery is an important research issue. The more frequently the opportunistic communication happens, the more the battery is consumed because the amount of data communication to exchange walking records increases. We need to develop a scheme to selectively exchange the records. Our trekking navigation system can be viewed as a multi-agent system consisting of autonomous behaviour to navigate the user considering the battery consumption and collaborative behaviour to share the walking records. How to coordinate the terminals with a constraint of battery consumption is an interesting research topic of multi-agent systems.



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