

# PERSONALLY CUSTOMIZABLE GROUP NAVIGATION SYSTEM USING CELLULAR PHONES AND WIRELESS AD-HOC COMMUNICATION

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## ABSTRACT

Due to the progress of portable computing devices such as PDAs, cellular phones and small sized PCs, many personal navigation systems have been developed which navigate their users to display routes to given destinations. Those navigation systems mainly focus on the guidance for personal use. In this paper, we have developed a group navigation system, which provides facilities for (1) personally customizable route navigation to a given destination, (2) management of group movement and (3) rehearsal usage when we make the personally customized route navigation. In our system, using wireless ad-hoc communication a few leaders of a group can collect and distribute the information about its members' current positions and give each member a suitable suggestion when the user is losing his/her way. The personalized route navigation scenario (program) running on portable devices can be obtained automatically only by clicking intersections sequentially on a given map and giving pictures and comments. A rehearsal mode is also prepared when we make the personalized route navigation.

## 1. INTRODUCTION

Recently, a lot of portable computing devices such as PDAs, cellular phones and small sized PCs have been developed. In such portable devices, GPS (Global Positioning System) and wireless communication facilities are provided. In Japan, KDDI provides a commercial service for personal navigation called *EZNavWalk* in its cellular phones where for a destination specified by a user, it displays the corresponding town map and a shortest route to the destination. The method for navigation is basically the same as that of car navigation systems. There are also a lot of researches for design and implementation of personal navigation systems (e.g. [1, 2, 3, 4]). Those approaches mainly focus on navigation of personal usage, and a standardized navigation scenario is used. There are few approaches for group navigation systems with route navigation and group management facilities.

In order to develop such group navigation systems, the systems should provide both the route navigation and group management facilities. If such a system is used only for

the purpose of reaching the destination, a simple standardized navigation seems to be reasonable. However, in group movement, there may be many cases that we want to use more personally customizable navigation facility. For example, if pictures of landmarks on the navigated route are displayed when the users approach those landmarks, those users can recognize their current positions more clearly. At a junction, if a picture of the direction of the travel is displayed, the possibility to lose the way may become lower. But such information may not be needed at all the junctions on the route. Depending on each position on the route, different information may be needed. In group movement, even if most of members do not lose their ways, a few members may lose their ways. Therefore, special attention may be needed.

In our system, a personally customizable route navigation facility has been developed where for a given town map we can only click the starting point and some intersections to the destination sequentially on the map. Then, the navigation scenario (program) running on portable devices is automatically derived. For each intersection, we can give the corresponding picture and comment in order to inform users of the navigation useful information. At the navigation time, such pictures and comments are displayed when each user reaches the specified intersections and/or landmarks. When a route navigation scenario (program) is developed, we may want to rehearse the developed navigation. For this purpose, in our system, we have a rehearsal mode of navigation where by clicking positions on a town map sequentially, the corresponding GPS information is sent to the developed route navigation scenario. Then, the route navigation scenario behaves as if it moves the clicked positions sequentially.

We have also developed group management facilities. We assume that each group member has only GPS and wireless ad-hoc communication facilities in his/her portable device, and that a few leaders have their own cellular phones to communicate with the server and other leaders. Using such facilities, the leaders of a group can collect information about the current positions of its all the members and distribute their current positions to them using wireless ad-hoc communication. They also give each group member a

suitable suggestion when the member is losing his/her way. If a member cannot reach his/her leaders in one hop of wireless ad-hoc communication, or if a leader finds the member is apart from a specified distance, the leader can send the member a warning using multi-hop wireless communication of the group members.

## 2. GROUP NAVIGATION SYSTEM

In our group navigation system, maps of several towns are held in a database provided by its server. We can also add pictures and comments for intersections and landmarks in those maps.

When we generate a group navigation scenario (program) which runs on portable devices, first we select a map from the database. Next, we click the starting position of navigation on the map. We continue to click intersections and landmarks on a route to the destination sequentially. Then, as shown in Fig. 1, a directed path from the starting position to the destination is obtained. We can also specify multiple paths from the starting position to the destination. Then, a directed graph for navigation is obtained. Our navigation scenario (program) warns its user when the user strays from one of the specified paths. To do so, as shown in Fig. 2, if the road from node *A* to node *D* is a curve, we can click intermediate nodes such as nodes *B* and *C* in order to avoid unnecessary warning for breakaway from the correct route area.

For each intermediate node on a path from the starting position to the destination, we can select a picture from our database which is useful to make the user understand his/her current position. If there is no picture in the database, the user can add his/her favorite pictures to the database. In addition to such a picture, we can also add a comment for each intermediate node which informs the user how he/she can find the way to the destination. For landmark nodes, we may add some explanations for those landmarks as text data. So, our navigation system may be also used as guidance for a group tour.

Finally, from the above information, the corresponding Java program is automatically derived. It guides the user to the destination. The derived Java program can run on several portable devices such as PDAs, cellular phones with Java executors, Windows PCs and so on.

The derived Java program for navigation checks its own position based on the information from its GPS receiver, and displays the current position on the map of the derived navigation system. When it reaches to the designated intermediate node, it displays the corresponding picture and comment to the user so that the user can recognize his/her current position on the route. If the user comes off the specified routes, a warning message is displayed as explained above.

Usually, all the data necessary for the navigation such as maps, pictures and comments are pre-installed to the portable devices. However, in some portable devices, due to memory limitation, a part of such data for navigation may not be held in the portable devices in advance. Also, a leader of a group may want to send new messages and/or pictures to all the



Fig. 1. Construction of Group Navigation Scenario

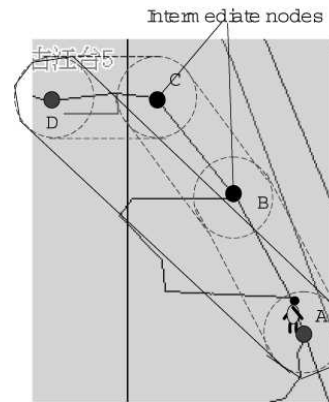


Fig. 2. Correspondence to Curve

members of the group when they are walking on the route to the destination. In such cases the leader can download the necessary data and distribute them to the corresponding member nodes using wireless communication. Since it is not realistic to assume that all the member nodes have communication facility via cellular phones, we assume that only the leader nodes have cellular phones and they act as proxy for other member nodes. In Fig. 3, we show an example of navigation.

## 3. GROUP MANAGEMENT ALGORITHM

In our system, there are two types of mobile nodes, leaders and members. We assume that only the leaders' terminals have communication facility via their own cellular phones and can communicate with the server. Each leader node collects the locations of members who can reach by one-hop's wireless communication. The leaders communicate

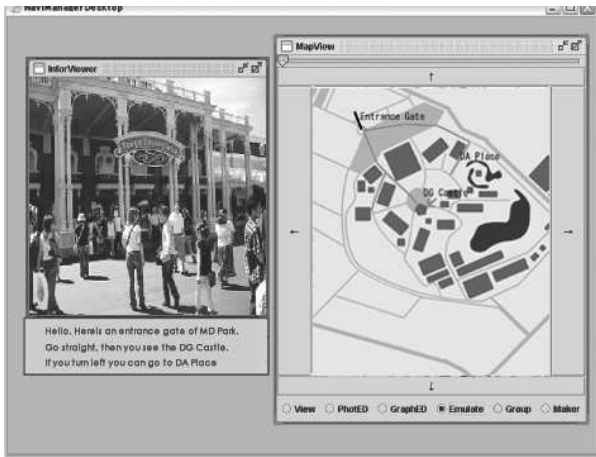


Fig. 3. Example of Navigation

each other using their cellular phones or wireless communication and exchange their members' locations. Then, the locations of all members who can reach to one of the leaders by one-hop's wireless communication are commonly held. That information is also distributed to all the members using wireless communication.

In general, there are some portable devices that do not have enough memory. Also, there may exist a case that the route (navigation scenario) and/or destination is changed on the way to the destination. In such cases, some group members may not have a part of the corresponding navigation scenario (program), pictures and text data necessary for the modified navigation in their portable devices. So our system makes the leader nodes acquire the necessary information from the server via their cellular phones and distribute the acquired information to all the members. Also, if a member node requires some information stored in the server, such a requirement is relayed by a leader node to the server. The corresponding reply message from the server is also relayed to the member. Thus, each leader node can behave as a proxy for accessing the server.

To do so, at first, each member node  $A$  broadcasts a **registration packet** periodically (about every 10 seconds). Each registration packet has the information about its location obtained from its GPS receiver and the member nodes that its wireless device can sense. If another member node  $B$  receives the packet, it adds  $A$  into its own **neighbor node list**. When node  $B$  broadcasts its own registration packet, its own location and neighbor node list are broadcasted. If a leader node  $P$  receives the packet,  $P$  adds  $A$  as its own **child node list**. All the leader nodes periodically exchange their child node lists each other by their cellular phones or wireless communication. The leader node  $P$  also broadcasts all the child node lists  $L$  periodically. Assume that node  $B$  receives such information  $L$  from the leader node  $P$ , and  $B$  finds that node  $A$  is contained in its own neighbor node list but it is not. In such a case,  $B$  recognizes that  $A$  cannot be reached from the leader nodes. Then  $B$  makes a list of such

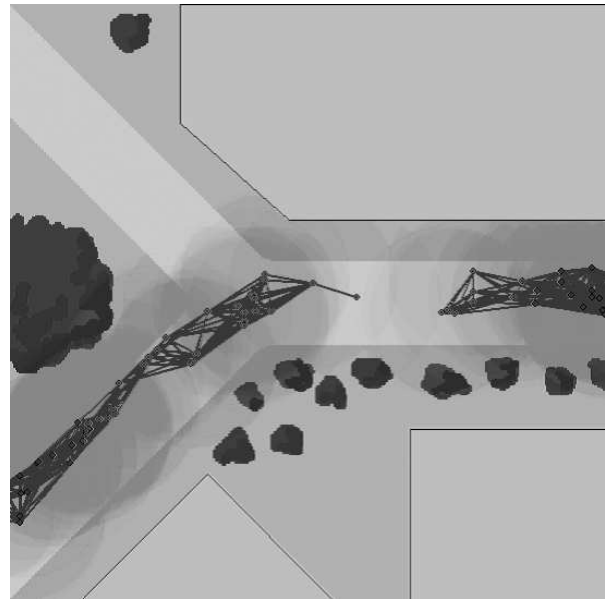


Fig. 4. Location of Member Nodes

unreachable nodes and sends the list to  $P$  by unicast channel. If  $P$  receives such list of nodes, it asks  $B$  to inform them that they are apart from the leader nodes and should come back to an area near one of the leader nodes. On the other hand, even if node  $A$  is reachable from node  $P$ , node  $P$  can send a warning message to node  $A$  when the distance between node  $P$  and node  $A$  exceeds a specified distance.

As the group management facility, on each leader node's display, we can display the current load map and the locations of all the member nodes which can reach the leader nodes. The network connection relations to show the possibility of wireless ad-hoc communication among member nodes are also shown like Fig. 4.

#### 4. SIMULATION

At first, we have evaluated the performance of the navigation server and checked the group navigation scenario (program) can be derived within one minute.

Then we have evaluated the performance of group management algorithm based on some experiments. We have simulated our system by using network simulator MobiREAL[5]. In MobiREAL simulator, we can specify each node's movement by a behavior scenario written in behavior specification language. So MobiREAL enables the evaluation of MANET applications in more realistic environments. We have assumed that 300 tourists have gone sightseeing of Kyoto as a group and 3 leaders have arranged themselves in suitable positions in the group. In our system, if a member is not found within its wireless range, the leader transmits a warning packet to the member and makes it return into the wireless range. The simulation result has shown that the

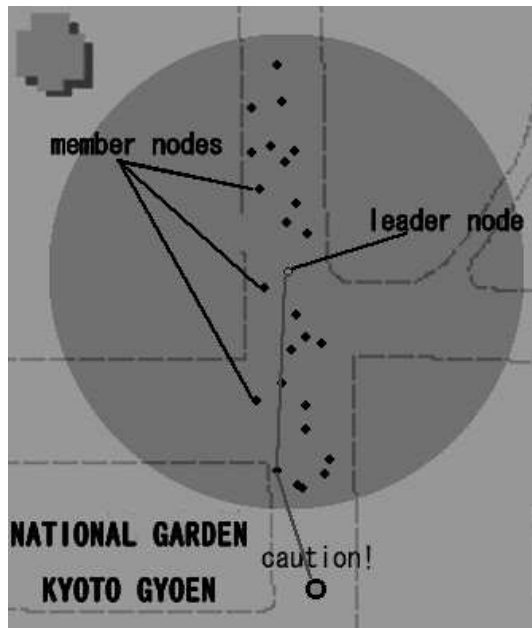


Fig. 5. Snap Shot of Simulation

leader can deliver a warning packet to each member who has come off from the group (white node with "caution!" in Fig.5), and maintain the group.

We have also measured the time a member has kept off from the wireless range. Fig.6 shows the time distribution of the node catching time for various values of the registration packet delivering interval. We have changed the transmission interval of the registration packet up to 20 seconds from 5 to every 5 seconds. When the interval is 5 or 10 seconds, the leader can catch all coming off members within almost 20 seconds. On the other hand, the member who cannot be caught exists for a long time when the interval is 15 or 20 seconds. Therefore our proposed group management system turns out to be effective, when the broadcast transmission interval of the registration packet is set within 10 seconds.

## 5. CONCLUSION

In this paper, we have proposed a group navigation system for multiple mobile terminals using GPS and wireless ad-hoc communication. In this method, only the leader nodes access the server in order to obtain pictures, texts and maps necessary for route guidance, and distribute them to their members using wireless ad-hoc communication. The group navigation system provide useful facilities for developing personally customizable route navigation to a given destination and management of group movement. From our experiments, we have confirmed that the derived navigation can work well. The design and implementation of group navigation are carried out efficiently.

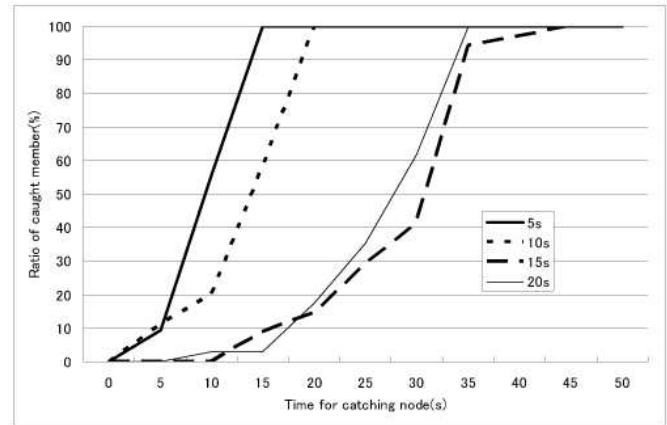


Fig. 6. Distribution of Node Catching Time for Various Interval of Registration Packet

For future work, we are planning to include a reasoning algorithm to our group navigation system for roughly estimating the location of mobile terminals without GPS receiver by measuring the strength of radio wave in wireless LAN among multiple nodes with GPS receivers. Indoor navigation where GPS cannot work well is also our future work.

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