ROUTE PLANNING AND SCHEDULING FOR WHEELCHAIR USERS

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INTRODUCTION

As human beings age, their physical abilities degrade. The proportion of population using wheelchairs increases sharply with age [1]. As the number of the elderly increases, the population of wheelchair users is very significant and increasing dramatically. Thus, finding accessible wheelchair routes is an important problem. Wheelchair users would like to find a path quickly and know the estimated travel time, but there is no existing system that shows up-to-date and detailed information about route accessibility. Thus, we were motivated to create route planning software installed on a small device to give wheelchair users route accessibility information while they are travelling.

Our software also contains a simple scheduler which synchronizes with a route planner to provide more detailed transportation information. If the user needs to head to a different destination because of a change to his/her schedule, the scheduler can transfer this information to the route planner. Then it will re-compute a path to the new destination. Furthermore, the route planner can announce the minimum required transportation time to the scheduler, which then provides an early reminder to the user.

We conducted user studies with potential users, both wheelchair and non-wheelchair individuals. Instead of being presented with a cumbersome and lengthy low-level path people, especially the elderly, would prefer a more cognitively relevant high-level path. Therefore, our system shows both high-level and low-level paths, which are available because our novel path planner finds paths hierarchically from coarse detail to fine.

RELATED WORK

With the increased need for caregivers for patients and the elderly, a number of *cognitive assistive technologies (CATs)* have been developed or are being developed. The Assisted Cognition project [5], the Nursebot project [7], the Aphasia project [6], the CLever project [2] and the Aware Home project [3] are some interesting developments. These projects have shown great success in helping the elderly and people with mental problems. Systems used in these projects are generally categorized into two types, reminder and routing helper systems. Our project is based on a reminder system, because with an accurate schedule, the destination can be easily obtained. Microsoft Outlook is a widely-used scheduler, while Autominder, ESI Planner II, and Adaptive Prompter are reminder systems created for special populations. On the other hand, the main purpose of our project is to aid wheelchair users to find suitable routes. Several existing systems, such as Lifeline and Activity Compass, provide pathfinding help to clients when they are travelling.

A number of systems have been developed to improve wheelchair physical behaviours. In [8], two low-cost wheelchair prototypes, *TinMan I* and *II*, help the handicapped avoid obstacles, reach pre-determined destinations, and maneuver through doorways. The paper by Yanco *et al.* introduces a robotic wheelchair named Wheelesley [9]. It includes indoor navigation and provides a user interface that can be easily adapted to a user's capabilities. In another project, the NavChair assistive wheelchair navigation system is proposed to reduce the cognitive and physical requirements of managing a powered wheelchair [10]. These robotic wheelchair projects have built realistic wheelchair simulation or actual wheelchair systems with high-technical hardware. However, they are limited to use in a localized area. A route planner incorporated into such robotic wheelchair systems would work more intelligently for users.

MOTIVATING SCENARIO

The Scheduler and Route Planner system can be useful in different cases. Two examples are discussed as follows. The first one describes a scenario for a wheelchair user who has used the system for a while. The user can reject a path that the route planner suggests to him/her, which modifies the system's known navigating ability of the user. The second example involves a new wheelchair user, who may need a more detailed description of the nodes on each path.

(1) Mary has been using a wheelchair for ten years. She is going to attend a talk at the Department of Computer Science (CS) at the University of British Columbia (UBC). She has little information about the building housing the CS department. With the Scheduler and Route Planner system, Mary inputs the destination of the event, and a path is found with detailed descriptions of which ramps and elevators she should take. Since Mary has been using the system for several months, it notices that some slopes and roads are too rough for her and eliminates paths invoking those slopes and roads.

(2) John, a student at UBC, injured his leg one month ago. He plans to buy some textbooks, but he doesn't know the accessible wheelchair routes from the bus stop to the bookstore. Therefore, he mounts a tablet PC with our system installed on his wheelchair. The route planner provides John with the easiest path, as well as relevant road conditions. John follows the route and arrives at the bookstore. After John buys the textbooks, the scheduler alerts him that he has a class in ten minutes. He checks the route planner again for the best path available to get him there on time.

THE SYSTEM DESIGN

We used prototyping, one of the Human Computer Interaction (HCI) related techniques, in the system design phase [4]. Through the prototyping process, we can not only define the interfaces of our final product but also test attributes of it before it is complete.

Low-Fidelity Prototype

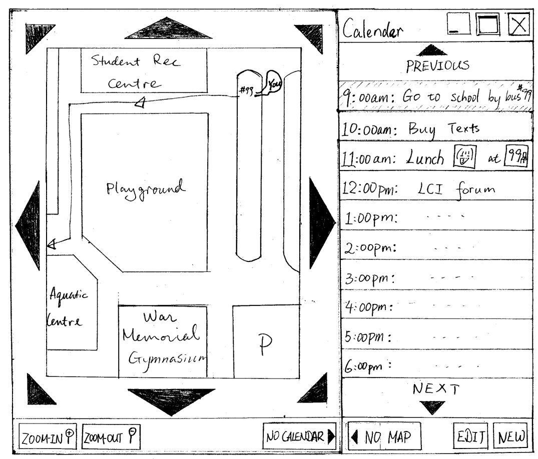

Figure 1: The paper prototype of the main screen

We employed paper mockup in the low-fidelity prototype period, because it is a cheap way of providing prototypes for testing and design improvements. Once design specifications were defined, we began by sketching the first draft of the main screen interface. The participants evaluated the sketch and giving possible feedback and suggestions regarding improper designs. Gradually, we collected all design ideas and optimized simplicity versus required functionality. With help from the participants, we finished the final paper prototype of the system's main screen, as shown in Figure 1. Although it is simple, it contains the two most important parts, the route planner and the scheduler. The participants were involved again in evaluating the final paper prototype.

Medium-Fidelity Prototype

After design requirements were finalized and the paper prototypes evaluated, we proceeded with medium-fidelity prototyping. Design adjustments were made based on final design requirements and implementation constraints. The main goal of the route planner is to display a suitable path for people in wheelchairs. The evaluation by the participants indicated that they appreciated that both an abstracted and a detailed paths are shown. First, the abstracted path can simplify the conception of the whole path for the client. Second, the detailed path shows the exact steps that the client needs to take.

High-Fidelity Prototype

In this section, we present several screen shots of the high-fidelity interfaces that are used as final system interfaces. They are done in Java using its Swing package. All of the design requirements and suggestions by the evaluators are met. After an event has just been entered, and if a path is found for that event, then the high-level path is shown as Figure 2. To view specific information about a place, the user can click the button representing that location. To view the detailed path, the user can click the "Detail" button, and then the screen will appear as shown in Figure 3.

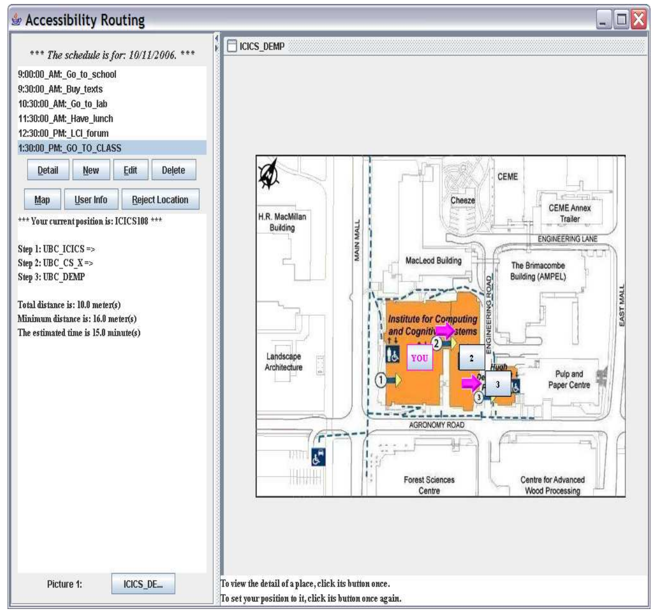

Figure 2: A screen shot of the Route Planner when a high level path is shown

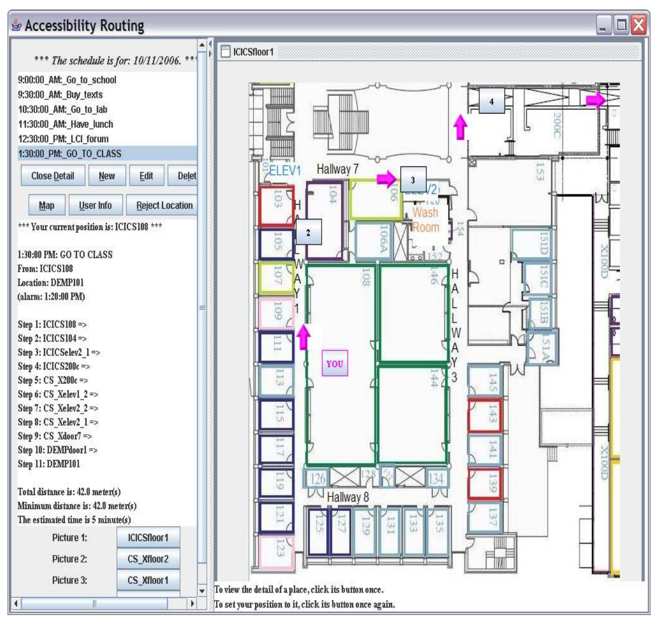

Figure 3: A screen shot of the Route Planner when a low level path is shown

USER STUDY

In this paper, we describe an evaluative study designed to address questions regarding the usability of our system, comparing the performance of wheelchair users and non-wheelchair users. We invited two wheelchair users and two non-wheelchair users. Evaluators are asked to perform a number of actions that assume they are students in CS at UBC, and are working in their research lab. Each participant takes about half an hour to complete the tasks. Their performances are measured in terms of correct and incorrect button clicks, total time, number of major questions, etc.

After the user study test, the participants were

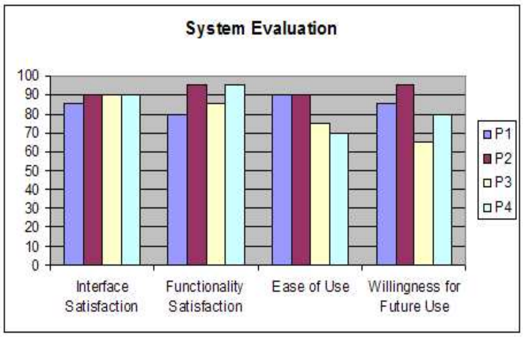

Figure 4: Evaluation of the Scheduler and Route Planner system

asked to evaluate four aspects of the system: interface design, functionality satisfaction, ease of use, and willingness for future use. Interface satisfaction refers to the user's satisfaction regarding the locations of buttons, the number of clicks to access a certain function, etc. Functionality satisfaction indicates whether the user feels satisfied with the provided functions. The chart shown in Figure 4 displays the results.

DISCUSSION

In this research, we have focused our efforts on building the Scheduler and Route Planner system, which can find both an abstracted high-level path and a detailed low-level path. In addition, the scheduler provides basic functions for users to keep track of their activities. In the system design and evaluation phases, we used interactive methods, which involved potential users to evaluate each level of system prototypes and the actual system. This evaluative study lets us realize user's need towards interface specification and functionality requirements. With desired functionality implemented, the new cognitive assistive system is able to contribute to helping users.

There are several areas where further research is required. First, the Java GUI interface implementation needs improvement. Second, the database could be enlarged to include more buildings and information. Finally, the system could be redesigned for other classes of users such as the visually impaired.

REFERENCES

[1] Disability Statistics Center: http://dsc.ucsf.edu/publication.php?pub_id=2&section_id=4

[2] CLever Project: http://l3d.cs.colorado.edu/clever/

[3] Aware Home Project: http://www.cc.gatech.edu/fce/ahri/

[4] Sommerville I. *Software Engineering.* 6th edition (2001) p. 171-191.

[5] Kautz H, Fox D, Etzioni O, Borriello G, and Arnstein L. An overview of the assisted cognition project. *accepted to American Association for Artificial Intelligence.* (2002)

[6] McGrenere J, Davies R, Findlater L, Graf P, Klawe M, Moffatt K, Purves B, and Yang S. Insights from the aphasia project. *in Proceedings of ACM Conference on Universal Usability.* (2003) pp. 112-118.

[7] McCarthy C and Pollack M. A Plan-Based Personalized Cognitive Orthotic. *accepted to AIPS.* (2002)

[8] Miller D and Slack M. Design and testing of a low-cost robotic wheelchair prototype. *Autonomous Robots* 2nd Edition (1995) pp. 77-88.

[9] Yanco H. Wheelesley: A robotic wheelchair system: Indoor navigation and user interface wheelchair. *in New York Springer* (1998) pp. 256-268.

[10] Simpson R, Levine S, Bell D, Jaros L, Koren Y, and Borenstein J. The NavChair assistive navigation system. *accepted to Workshop on Developing AI Applications for People with Disabilities* (1995) pp. 167-178.