DESIGNING A USER INTERFACE FOR A PDA-BASED CAMPUS NAVIGATION DEVICE

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University campuses, like many other public and private institutional settings, pose challenges to visitors and newcomers finding their way from place to place. In some cases, such campuses have grown to the size of a small town. Maps and tour guides have traditionally been the means used to assist visitors find their way; however, the recent development of high-power, low-cost mobile computing opens the door to portable electronic navigational aids. This paper focuses on user interface concerns in a personal digital assistant (PDA) based campus guide. Cognitive and visual display engineering principles are used to develop a preferred preliminary design. Subjective feedback and quantitative data on the user interface are gathered in a small pilot study. The appropriateness of the design and its implications for future work are also discussed.

INTRODUCTION

As higher education has thrived over the last one hundred years, our universities have become sprawling campuses. In many cases these campuses make up a large portion of the cities of which they are a part. This setting is similar to dozens of others at large public and private nonacademic institutions. However, it presents its own unique challenges to visitors and newcomers alike.

Traditional methods, such as maps and campus tour guides, are regularly used to make finding one's way around easier. While these methods have proven to be quite effective, advances in technology open the door to an entirely new means of campus navigation. Previous attempts at electronic tools, like Cyberguide (Abowd et al., 1997), have been afflicted primarily by bulky hardware and high costs. Today, the technology required for such a system is not only available off the shelf, but also comes standard on most personal digital assistants.

Given that the means to create a high quality electronic navigational tool are readily available, it is necessary to evaluate the human factors and ergonomics associated with such a device's user interface. The most obvious target platform for a campus guide is a personal digital assistant, or PDA. These handheld computers now have the capabilities and features needed to implement a comprehensive navigational aid. The remainder of this paper discusses user interface (UI) concerns in a PDA-based campus navigation device. The hypothetical device is referred to as the Campus Computer Location Expert Guide (CCLEG), or more simply as the Expert Guide.

The sections that follow discuss the characteristics of an optimal navigation system, present a prototype UI which attempts to implement those characteristics, and outline experimental data gathered during a pilot study with the prototype. The final sections provide insight into the next steps for the Expert Guide and draw some more general conclusions as to the nature of all handheld electronic navigation aids.

OPTIMAL NAVIGATION SYSTEM

From a human factors standpoint, one of the more interesting problems for the Expert Guide is how to best depict navigation instructions. There are several different approaches to this problem, each with their own set of benefits and drawbacks based on their degree of egocentricity. The least egocentric navigation option would be to employ a top-down, North-up view of campus and require a user to travel along an intended path that would be highlighted onscreen. It goes without saying that this is a less than ideal means of directing a user along a particular path. The spatial memory requirements for mentally rotating the North-up map alone are large (Aretz, 1991). It would be nearly impossible for a user to enjoy one's visit to campus since his or her nose would be buried in the screen of the PDA.

A slightly more egocentric variation of this approach would be to use a top-down map that rotates so that "up" always faces the current direction of the user. This provides only a marginal decrease in mental requirements for the user as the spatial data onscreen still must be interpreted and translated into the necessary changes in direction.

Taking egocentricity to the extreme, the PDA device might display a 3-dimensional representation of what the user is currently seeing with arrows indicating the next direction of travel. Though this approach might be the best in terms of immersiveness, it is somewhat impractical due to limitations of graphics processing on most PDA devices currently available.

Dynamic Route Lists

If each of these strategies is inappropriate, what then is the best way to get a user from point to point? One of the most common means people employ to give directions is a route list. A route list simply is a sequence of step-by-step directions from point A to point B. Such directions tend to be highly egocentric and can make use of various landmark features available during travel. Research has shown that route lists have lower user error rates, shortened decision times, and reduced mental effort when compared to paper maps in driving tasks (Wickens & Hollands, 2000).

Many commercial navigation aids intended for drivers make use of route lists. Popular online systems like MapQuest present users with a series of maneuvers that direct them from their starting location to their specified destination (Mapquest, n.d.). These directions consist of prompts like "Merge onto I-80 E via exit number 87A toward DAVENPORT." Landmarks, like Davenport and exit 87A, are incorporated to enhance the directions given.

Thus, it seems users of the Expert Guide would benefit from directions given in this manner. Unfortunately it is not sufficient to assume that the Expert Guide can generate a list of directions from one place to another and the user will follow them exactly. People get lost, and people take side detours. Therefore, the optimal system must account for such errors in deviation from pre-destined paths.

In order to allow for such changes, dynamic route lists (DRLs) can be implemented. The fundamental ideas behind DRLs include dynamically re-generating the route list when the user gets off the intended path, and presenting each step of the directions only when needed based on the user's current position. While not formally defined as DRLs, many current day systems make use of this approach. The purported advantages of using DRLs are as follows. Verbal presentation of information in a textual format avoids conflicting load on the spatial working memory being used for other tasks while traveling. Context sensitive route lists can be highly egocentric, providing directions such as "turn left at the next sidewalk." They also provide a simple and natural interaction style that is important in systems that require a low learning curve.

USER INTERFACE PROTOTYPE

The user interface prototyped in this study is designed around the dynamic route list concept mentioned in the previous section. In addition it incorporates a variety of features that add to its overall ergonomic effectiveness. Figure 1 illustrates a sample instruction in the user interface we developed.

The prototype is designed with screen dimensions matching those of typical PDAs on the market today. The sample direction given shows several important aspects of the interface. The arrow labeled "A" points to the area of the screen that is used for basic egocentric directions. These instructions are presented in the largest font in the interface, as they are likely to be the most useful to a user. In addition to a text prompt like "TURN LEFT" it incorporates a dual encoding of the instruction using a corresponding left arrow icon. Basic icons for the four cardinal directions and the four diagonals are easily portrayed. Not all navigation on a campus is as easy as "turn left" and "turn right," however. The interface allows for more advanced or composite directions and their corresponding icons. Figure 2 illustrates a more complicated instruction telling a user to cross the street immediately ahead of him or her.

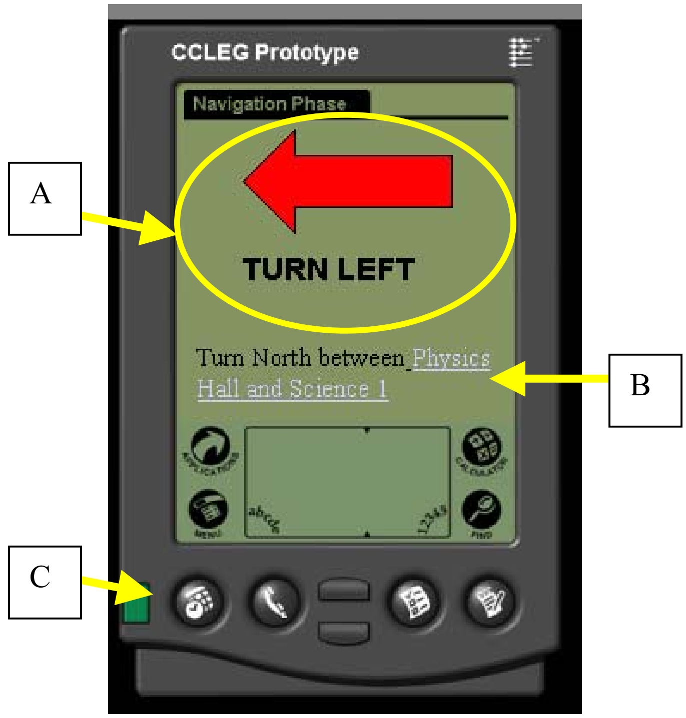

Figure 1: User Interface Prototype

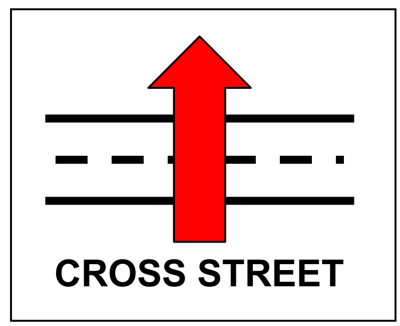

Figure 2: Iconic Representation for Crossing a Street

The proposed interface supplies numerous features beyond the basic navigational instructions. Arrow "B" in figure 1 points out additional context instructions given for each basic prompt. In this case, it helps clarify not only the direction to turn, but it also gives additional information about the exact location of the place to turn. This affords system designers a means of communicating both exocentric and landmark information. Combined with the basic instruction and icon, the triple coding of data helps ensure the desired message is interpreted correctly.

In this example, the system also has additional data about one or more items in the instruction, specifically the Physics Hall and Science 1 buildings. Hyperlinks are used to denote such situations and can be "clicked" to obtain information ranging from a picture of the building to a list of offices and services within that building.

Arrow "C" from the same figure directs attention to the six physical buttons located at the bottom of the PDA. While models vary, most PDAs on the market today have anywhere between four and ten hardware buttons in a similar position as those on the prototype. These buttons can be used for a number of purposes other than those originally intended. During the navigation phase, there are certain tasks that are most crucial to the device's operation. Intelligent utilization of these hardware buttons is especially important for the Expert Guide. If tasks are inappropriately assigned, a higher dependence on a stylus pointing device could result. This could have significant disadvantages because a stylus can be easily lost while walking around campus. From left to right, the prototype's four main buttons do the following: view the previous instruction (similar to the back button in an internet browser), show a top down "You Are Here" map of the campus, access a web browser to pull up additional campus information, and choose a new destination.

A system like the Expert Guide is sure to contain many more capabilities than those outlined above. Ideally it would also make use of extensive online resources to give additional context-specific information that might relate to each individual user. While this prototype does not explicitly deal with such issues, it does not impede their future addition unnecessarily. Most importantly, it contains the features most essential to the campus navigation component of the system and is robust enough to allow for preliminary usability analysis.

PILOT STUDY

Methodology

The aforementioned user interface prototype was implemented in order to gather basic feedback on its appropriateness to the task of campus navigation. Due to time restrictions, the system was implemented in a "low-tech" manner. Rather than implementing a GPS-driven, PDA-based model, the interface was rapidly prototyped using everyday computer hardware and software. Three routes were pre-determined on the Iowa State University campus. Directions and context information for these routes were then entered into a series of Microsoft PowerPoint slides on a notebook computer. The end result was a 43-slide presentation in which each slide corresponded to one step in the dynamic route list or one piece of contextual information. Figure 1 is an example of one particular slide.

Just as in the proposed user interface, the buttons located at the bottom of the PDA were overloaded to perform specific functions in the prototype. Context information, such as pictures of buildings along the routes, was also added and hyperlinked in the mockup. However, rather than physically depressing a button or tapping the screen with a stylus, test subjects were required to use the mouse to press the virtual buttons. Audible prompting was also included in order to ensure that users noticed a change in the directions given. Of course, not all features were implemented given the intended scope of the study. Functions like web browsing and "you are here" mapping were merely stubbed out in the interface.

Test subjects were then asked to navigate the pre-determined routes around campus carrying the laptop and using only the information provided by the slides shown on the screen. Rather than implementing GPS tracking to trigger transitions between slides, an off the shelf wireless PC remote control was used to advance the presentation. Administrators of the tests walked along with the subjects in a manner which allowed them to signal the next navigation instruction using the remote, record the amount of time between origin and destination, and make note of any errors the subject made. Since the initial prototype did not allow for rerouting, any deviation from the intended path was considered an erroneous navigation decision.

Following each trial run, subjects were asked to complete a usability survey that solicited demographic information and gathered suggestions for improvement in a future prototype. Quantitative trial results and qualitative survey responses are presented below.

Results

Trial runs were conducted with a small group of subjects made up of visitors to the ISU campus, undergraduate students, and graduate students with varying degrees of familiarity with the campus in general. Because of outdoor navigation and severe winter weather at the time the tests were administered, only five subjects completed the trials. Of these, two had previous experience with commercial navigation devices and three had prior experience with PDAs. The small sample size, while limiting for statistical purposes, still provides a basis for questions regarding the worthiness of the proposed UI.

Table 1 presents the data gathered for each of the three paths around campus in the trial. Columns two and three display the average time to destination in minutes and the average number of navigation errors respectively. Each cell contains the average value followed by its standard deviation.

Table 1: Trial Run Results

PATH	AVG Time (min)	AVG Errors
1	5.60 / 0.55	0.60 / 0.89
2	11.60 / 0.45	0.20 / 0.45
3	8.50 / 0.58	0.50 / 1.00

Notably, there is little variation in the average time to destination for each path, and the average number of errors is quite low. The few errors that were made by subjects tended to be due to a missed cue caused by an inattention to the screen or a noisy distraction such as a passing bus. Overall, the average number of errors per minute in the test was 0.05. Low error rates do not contradict the hypothesis that this method of presenting directional information for users on foot is effective.

Survey data also support the quality of the proposed design. Table 2 depicts responses to a series of items on the usability survey completed immediately following each trial. Values are based on a Lickert scale of one to five. In the first two questions, a response of five represents the highest degree of familiarity. In the remaining four statements, five corresponds to the most favorable response.

Table 2: Survey Responses

ITEM	AVG VALUE	STD DEV
How familiar are you with the campus in general?	3	1.22
How familiar are you with the specific routes?	2	1.41
Rate the ease of use of this device.	4.8	0.45
Rate your comfort with this device.	4.8	0.45
Rate the clarity of the navigational instructions	4.8	0.45
Rate your overall experience with the device.	4.8	0.45

In addition to the numerical data gathered, users were asked to complete a series of open response questions designed to determine if there were any problems or improvements that should be addressed prior to moving forward with this design in a PDA-based system. Responses to these items showed that users found no major outstanding problems with the design. However, a few users suggested ways to improve the presentation of each instruction and requested features, like an onscreen compass, that are dependent on integration of real time tracking. These recommendations could easily be incorporated into future work on the Expert Guide.

FUTURE WORK

The current Expert Guide project is a long way from becoming a mainstay of the Iowa State University campus tour. Almost all of the hardware and algorithms required exist today; however, the project is still in the early stages of the development lifecycle. In addition to actual implementation and refactoring, further usability studies are in order.

PDA Based Prototype

The clear next step in development is to determine the target PDA platform and create a prototype designed for it. Whichever PDA and operating system are selected, they must have a few basic capabilities. Location and tracking are perhaps the most crucial aspects in the success of this system. Advances in Global Positioning System (GPS) technology now provide an accuracy of within three meters (Garmin, n.d.). GPS is the ideal candidate for position finding outdoors. Several PDAs today have GPS built in or are capable of supporting it with add-ons.

Another foreseeable hardware restriction would be the need for wireless network communication. Recent research has made use of PDAs and IEEE 802.11b wireless networks to stream active content to museum goers (Grinter et al., 2002). In order to overcome the storage limitations of PDAs and provide a large amount of information about campus, it would be necessary to offload the content onto external servers. Wireless TCP/IP links would allow for quick retrieval of this information with little to no user inconvenience. In fact, the 1997 Cyberguide project somewhat limited users because of the unavailability of high quality, low cost wireless hardware (Abowd et al., 1997). The Expert Guide could exploit these advances.

Following the selection of hardware, development of the Expert Guide software should be reasonably straightforward. The most crucial system, naturally, will be the dynamic routing mechanism. The complex nature of tracking users and re-computing instructions en route make this the most inherent hurdle in the software development.

Knowledgebase Generation

A non-navigational concern with the Expert Guide's future is the creation of a vast knowledgebase that can be accessed quickly and seamlessly from the PDA. At the very least, a database containing pictures of all buildings on campus will need to be created to provide landmark data for all possible routes across campus. Much of the other data needed for the system is already available electronically, but it will need to be organized and stored in a suitable fashion for retrieval over the wireless links.

Researchers at Cornell University have developed a PDA-based tour augmentation system called CampusAware that provides a delivery method for such context information (Steele, 2002). Given demographic information provided at the start of a campus visit, the system tracks the device's location via GPS and displays appropriate information when users enter a region of interest.

Large amounts of data like this pose several interesting problems for the system. Though techniques used in CampusAware provide a starting point, efficient and ergonomic means of displaying context sensitive and user-requested information need to be further explored.

In-Depth User Study

A major limitation of the current work is that it lacks a statistically rigorous analysis to determine the effectiveness of the system. After a PDA-based prototype that uses GPS for tracking has been developed, it will be necessary to re-examine the study here and ask additional questions. It is possible that the small sample size masks underlying issues. It is also likely that the usability responses will be somewhat different when subjects are using a real PDA rather than a virtual one on a laptop screen. Another important question to be concerned with is whether or not navigation with the Expert Guide is more effective than traditional means. In other words, is all of this really worth the cost and effort? Studies using control groups with maps would be helpful in answering this question.

CONLCUSIONS

Though this study did not develop a final product for the Expert Guide, it is reasonable to say that comprehensive devices like this will be developed in the near future. Technology required to implement the Expert Guide is now commercially available. The work presented here adds needed human factors insight that can be beneficial in the development of an end product. A navigational tool like the Campus Computer Location Expert Guide is not only feasible from a technical standpoint, but it also seems within the abilities of system engineers to design a product that is ergonomically effective. Dynamic route lists allow for the necessary information to be presented while at the same time minimizing the overall cognitive load imposed on users.

The limited sample size of the test group in this study prohibits concrete conclusions, but users unanimously felt that navigation with the Expert Guide was better than using traditional means. This study also shows that such user interfaces need not be highly elaborate or require an extensive training process to be effective.

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