Intelligent Library Navigation using Location-aware Systems – The Newman Project

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ABSTRACT
Finding resources in an indoor facility can be a difficult task, especially for patrons who are not familiar with what the facility has to offer. Current methods of indoor navigation involve the use of static maps, directions posted on walls and other traditional systems. However, as we see greater mobility of always-connected computing devices, we believe a better solution can be developed. As campuses and facilities begin to be covered with wireless internet access, we can access the web seamlessly from any location. In this paper, we explore the possibility of using a handheld device that can leverage that technology to search for and locate services and resources within a library. By displaying maps with directions and introducing several other features to aid library exploration, we believe we can reduce search and retrieval times as well as enrich the user experience.

Categories and Subject Descriptors
H.1.2 [**Models and Principles**]: User/Machine Systems – *Human Factors*; H.3.3 [**Information Search and Retrieval**]: Information Search and Retrieval – *Information Filtering, Relevance Feedback, Search Process*

General Terms
Algorithms, Design, Experimentation, Human Factors

Keywords
Indoor navigation, information retrieval, location-based system, library navigational tool.

1. INTRODUCTION
It can be challenging to find items in indoor facilities. Among the challenges of indoor navigation and resource finding are limited space and mobility, the sheer amount of artifacts that may be stored in a limited space, and the clutter of these artifacts due to the limited space. Under these constraints, information retrieval for indoor facilities becomes a time consuming task if a potential user is presented with too much information. We look to address these issues in a library—an exemplar facility in which these problems apply. The Newman Library at Virginia Tech holds more than 2 million physical volumes and several other forms of media such as films and maps across six floors [7]. Finding the right book in the least amount of time in such a building can be a daunting task.

As a potential solution, we explore the possibilities of systems with wireless connectivity and location-tracking. Location-based systems provide needed information and services to users based on their current location. Examples of these systems range from in-car GPS navigation systems to Meetro's social networking suite [5].

The Newman Project, a location-based system, helps users in several ways that we believe can enhance the library experience along with reducing the amount of time required to look for resources in a large indoor facility. A combination of book searching, route planning, resource finding and progress lists techniques are some of the initial features we are using to solve the various problems of indoor navigation mentioned above, which are implemented in the first version of our system. The Newman Project displays a current physical map view of the user's position and also uses Mapquest [8] like directions to direct the person to the resource they are trying to reach. By integrating our searches and queries with the library information system we are able to better locate the points of interest and guide users to them. A great degree of emphasis was placed on understanding the conventional activities performed by users in a library to both support and streamline those features. The Newman Project system operates on handheld computers that are equipped with Wifi® [14] internet access capabilities. It utilizes our previous work on indoor location-tracking called the seeVT Location Based Notification System.

In this work, we had representative students and employees of the library evaluate our current implementation. Many felt the current system was fairly adequate but were able to identify areas for improvement. Overall, our prototype system was well received by the evaluators who believed it enhanced the library experience by greatly improving the efficiency of the time spent performing search tasks.

2. RELATED WORK
Finding resources in a library is not a new or unique problem. Searching an indexed list of call numbers has become the standard technique for finding resources in the library. Over time these searches have become more sophisticated and with advances in

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indoor navigation techniques, the process of finding library resources has become more efficient.

2.1 Current Tools for Library Searching

The majority of larger libraries today employ a text-based search engine that is essentially an electronic card catalogue returning information about relevant matches like the call number and title. The Annerberg Resource Center's electronic card catalogue at USC for example allows the user to select a letter, after which the system returns a list of all titles (or authors) beginning with that letter, including the call number, publisher and number of copies [1]. These systems have an advantage over the traditional card catalogue in that they are more user friendly, more secure, and are able to include dynamic information like whether a book is available or not.

Although these systems are very useful they are designed for use on a desktop computer. The results tend to have more information than is necessary to find the desired book in the library. For example, the Virginia Tech library uses a search engine called Addison, which returns a list of possible matches including the title, date published, and the number of entries (figure 1) [12]. But in order to learn the call number you have to click a link to get to a second more detailed results page (figure 2). This exhaustive list of search results is unsuitable for a handheld device given the limited screen real estate. Also, the results of the search have no information about where a book is physically located in the library leaving it up to the user to figure out where it is.

No.	Mark	TITLES (1-12 of 245)	Year	Entries 277 Found
1	☐	The dog.		3
2	☐	Dog adoption : a guide to choosing the perfect "pre-owned" dog from breeders, dog racetracks / by Joan Hustace Walker.	1996	1
3	☐	Dog aggression / [videorecording].	1998	1
4	☐	Dog ailments : recognition and treatment / by Eddie Straiton.	1989	1
5	☐	Dog anatomy : a coloring atlas / Robert A. Kainer, Thomas O. McCracken.	2003	1

Figure 1. Sample search result page from Addison.

Figure 2. A more detailed results page from Addison.

2.2 Location-Based Systems

The initial thrust for Location-Based Systems (LBS) comes from outdoor scenarios such as finding directions to a location, or getting to know where the nearest restaurant is. Great examples of these are Google Local [6] and Windows Local [15], which provide geo-referenced information about businesses, services and events in a particular area. These are excellent services to use outdoors, however these systems typically rely on satellites and so are unsuitable for indoor location-tracking.

We believe that there lies a rich opportunity for LBS in indoor facilities. Trying to find resources in a building can be quite challenging at times. Businesses could prosper greatly if they were able to direct customers straight to the products they were looking for, thereby enhancing the user experience. These systems could also be used for inventory control scenarios, where finding the current location of items would be vital to maintaining production standards, etc.

2.3 Current Indoor Navigation Techniques

The REAL system was developed at Saarland University in 2002 as a guide for pedestrians. The system was designed to use multiple location tracking technologies allowing the user to be guided both indoors (using RF or Bluetooth) and outdoors (using GPS). The REAL system requires the installation of radio transmitters throughout a building in order for it to operate properly indoors and consists of multiple hardware devices the user must wear to operate the system. While this system focuses on bringing seamless navigation between indoor and outdoor environments, it is excessive for our purposes. The Newman Project is focused on indoor navigation and one goal is to require a minimum amount of extra hardware and infrastructure setup to get the system working.

"A hybrid indoor navigation system", submitted to the ACM from the University of Saarbrücken in 2000 [2], discusses an indoor navigation system using sets of information booths in buildings that would communicate with various forms of mobile devices. One feature that was discussed was the reorientation of a map to the user's egocentric point of view. We would have liked to be able to do this but with the WiFi infrastructure already in place we had a resolution of about 10 meters so determining a user's orientation would be impractical. This group also discusses techniques to adapt their application to be used on different portable devices or to adapt to different resolutions of location tracking in different buildings. This is not the case with the Newman project as our application is designed for use at a specific location using similar handheld devices.

2.4 Notification Systems

Location-based systems are often used to provide users with needed information while they are engaged in a physical task such as driving or walking to some location. Naturally, the user will need to divert attention to and from the location-based system as it notifies the user of information. Notification systems provide an ideal platform on which to develop location-based systems. Notification systems are interfaces which provide reaction to and comprehension of valued information in an efficient manner without producing unwanted interruption to a primary task. These systems are primarily used in divided attention, or multi-tasking situations [9]. Notification systems must support attention allocation between tasks, but at the same time support access to additional information. We can leverage a design framework for notification systems centered on three critical parameters: *interruption* (I), *reaction* (R), and *comprehension* (C). Interruption is the intentional reallocation of attention from the primary task to the notification; reaction is the immediate response resulting from a notification; and comprehension is user understanding of the information that is processed, related to existing knowledge, and stored in memory for future use. Through the IRC values, we were able to more effectively define

design goals for and evaluate our progress in developing our location-based notification system.

3. THE NEWMAN PROJECT

The Newman Project is the working title for the research and work done in the fall of 2005 to further our understanding of indoor navigation systems and resource finding. It is named for the Newman Library at Virginia Tech, the building for which we started making the system. After identifying what problems most people have with campus libraries and the key concerns of the library staff, we compiled a list of common problems and possible solutions.

We found that many of the users had concerns with the searching process; it was too confusing and usually had superfluous information. In addition, most users had difficulty in physically locating the book since they were unfamiliar with the library's layout. Finding multiple books was also frustrating, as without knowledge of the library's organization, the patron usually passes several of their desired books while remaining focused on finding one particular selection. This paper explores these problems in greater detail and presents the features of the Newman Project that address them.

3.1 Library Activities and Their Problems

3.1.1 Searching for Needed Resources

Using conventional methods to find a book in a library, you would first need to locate a computer or other searching tool to look up the book. Then, you would need to navigate through multiple screens to try to find the information about the book that is pertinent to tracking the item down (call number, title, author, etc). If searching for multiple books, you would need to write down or remember the various bits of information relevant to your searches. This process can begin to become increasingly problematic as the number of resources or complexity of resources increases.

3.1.2 Navigating to Available Resources

In larger libraries it may not be obvious how materials are organized or categorized. Once you find the right section you may still have to go through many shelves of books to find what you are looking for. When looking for more than one book you are not likely to use the most efficient path to find them, often passing a book that you also want on the way while being focused on locating another one.

3.2 The Newman Project's Solutions

3.2.1 Location Tracking Using SeeVT Framework

The user's current location is tracked using the SeeVT framework. Utilizing the campus wireless network that covers all of the academic buildings, the system determines where it is by checking the signal strength of the surrounding wireless access points. An algorithm is then applied to determine which location the device is at [11].

The user's current location is always displayed on the map with a maroon-colored circle. As the user walks through the library, the program refreshes itself to check whether or not the user has moved closer to another access point. If such is the case then the map updates itself with the user's new location. The user can view any floor of the building at any time by clicking on one of the numbered buttons on the side. This allows users to check what is on other floors without having to physically move themselves to them.

3.2.2 Searching Integrated with Maps

The Newman Project's built-in searching feature accesses the library database of books using AirPac, a new search system for wireless devices that is currently not available for regular student use [13]. The information returned from the AirPac search is parsed by the program and only the book title, author, call number, and availability are displayed on a single page that is easier for the user to interpret than conventional searches. Once a book is selected, a colored dot will appear on the map indicating the book's location. The user's current position and the location of the book are connected by a colored line indicating the shortest path as determined by Dijkstra's shortest path algorithm (figure 3) [4].

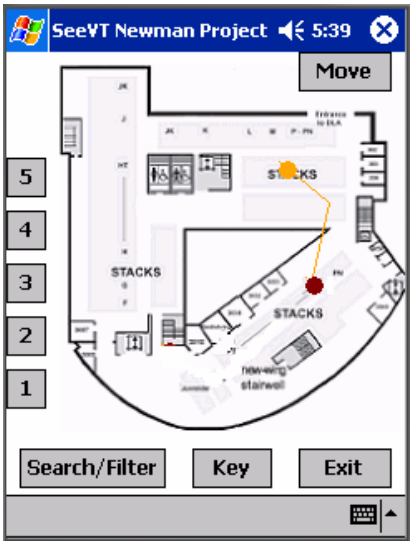

Figure 3. The shortest path drawn from the user to the book.

Should the item of interest be located on another floor, the Newman Project will direct the user to the nearest stairwell or elevator to ascend or descend to the appropriate floor, and the path will continue from there.

This feature ensures that users do not waste time wandering around the building looking for a specific book while passing right by another on their list, or the case of this library which is mainly circular, prevents them from walking around the floor in a circle when the book is actually 50 feet behind them.

3.2.3 Database of Points of Interest

Other useful library resources that patrons may wish to locate in the library include stairs, computers, copy machines, restrooms, etc. Due to the limited screen space provided by the handheld device, a color-coded classification system was implemented to represent these various points of interest (figure 4). To keep the screen from becoming cluttered with several different colors, the user has the option to only display which features are highlighted on the maps at any time.

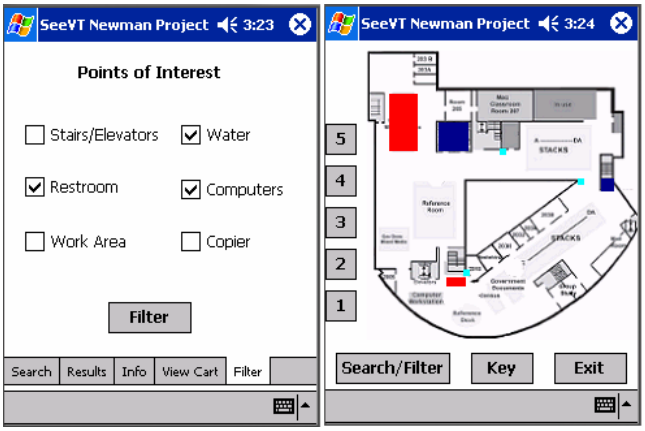

Figure 4. User-selected features to display and updated view.

3.2.4 Multiple Book Search

Locating multiple books is made simpler with the Newman Project. The user has a "cart" similar to many online shopping websites that keeps track of what books have been selected so far. A user is free to add or remove any number of books to this cart and perform different searches.

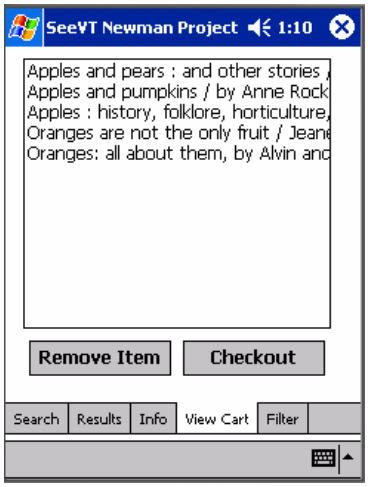

Figure 5. The "cart" that holds the user's selections.

When he or she is satisfied with their selections, a click of the "Checkout" button displays every selection on the map, with the shortest path drawn to the nearest book (figure 5). While navigating, if the user moves off of the path and ends up closer to another book, the path will be automatically redrawn to the closer location. This ensures that the user is always aware of the book closest to their present location, so time is not wasted wandering around looking for another book.

3.2.5 Recommender for Related Books

When users search for a book on a particular topic, they are likely to just select one or two from a list of many that fit the search description. Very rarely will they take the time to locate every book that is returned from the search query. The Newman Project stores a list of the other books that were high on the relevant search return list but were not selected by the user. When the user passes by one of these books, the device makes a sound and displays a message informing a user that a resource is nearby that may be relevant to the search and the name and call number (figure 6). This gives the user the chance to find the other book while they are in the area, but also the option of ignoring the suggestion and continuing on their path to their destination.

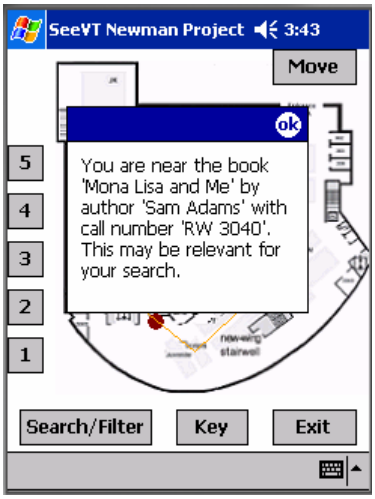

Figure 6. Recommender suggesting a related nearby book.

3.3 Design Methodology and Tools

3.3.1 Extreme Programming

The application was developed using extreme programming—an agile software development methodology [3]. We held regular correspondence with Ms. Annette Bailey, Digital Assets Librarian at Newman Library, to discuss our progress and keep updated on tasks. In keeping with the extreme programming guidelines, we ensured that our work was to her specifications. We found that this process worked well, as each member of the group was kept abreast of the project's progress.

3.3.2 Scenario-based Design

To guide the development of the Newman Project application interface, scenarios and claims were written to organize our thinking and detail the projected flow of the system [10]. We wrote various scenarios of how we expected people to use the system and then created claims from the discussed features to highlight their positive and negative aspects.

3.3.3 Microsoft Visual C# for Handhelds

The Newman Project was developed as a mobile application using Microsoft Visual C# .Net 2003. Visual C# supported a smooth transition in porting the application over to pocket PC's running Windows CE when development was completed.

4. USABILITY EVALUATION

In our pilot evaluation of the Newman Project application, we first set out to evaluate a more conventional method of library searching and then compare those results to those of the application. In current methods for library navigation, users search for a particular book or list of books using a database provided. Upon searching, the user must decipher multiple screens of search results to retrieve useful information.

The Newman application set out to combine the power of traditional search methods with the simplicity and intuitiveness of

maps. By integrating a searching method with the pinpointed location(s) of the search results on maps, we expected the users to make a smooth transition when navigating to the resources of this indoor environment. To accomplish this smooth transition, the results are immediately displayed on the screen through the maps. The immediate display of results on the screen focuses the user to stay on his or her primary task (of searching for a book) without any other distractions, which in essence leads to a high reaction level on the user's part.

Upon testing this through evaluation, as expected, the transition from a simplistic search to immediate feedback displayed on the map yielded positive results. Users felt that the transition allowed them to more efficiently identify what they were searching for. This task was also accomplished effectively without the users being distracted from their goals. In general, the users that tested the application said that they preferred a simple search and immediate feedback as opposed to giving them more control over the searches and display properties. Allowing the user to create more advanced searches on a handheld would become more of a distraction to the user due to the limited space and functionality provided by a handheld device.

One of the other features focused on for evaluation was the navigation of the user through the library. For this task, it was necessary that we provided the user with features requiring a minimal amount of interruption, but with a fair amount to reaction and comprehension. Traditional methods of library navigation require high levels of interruption if you are using maps provided by the library. The user is constantly switching their attention between the resource they are finding and the map. Using the seeVT location-based tracking system, we take this technology a step further and provide drawn out pathways based on the user's current position and their destination. These pathways provide the user with information that allows the task of navigating towards a book flow smoothly and efficiently.

When testing this feature of the application, users experienced much greater efficiency in the time required to locate a particular artifact. Through the location tracking, the users were continuously aware of their environment and where they were within it. In being aware of their environment, the users felt that they did not need to rely on the application for support, hence achieving our goal of a low interruption system. The users simply needed to determine their location by quickly glancing at the application and then using the path on the application to determine where they were navigating to.

However, the limited amount of interruption that does occur within the application is due to the library recommender. As explained previously, the recommender takes elements from a previously conducted search relevant to that users search, but did not directly choose to search and locate within the library. While we did not want to completely disrupt the task of locating a book, it was believed that user searching for books within a library may also want relevant information related to their search.

Users can become daunted with the task of having to search the locations of a large amount of books. Because users may not be able to search for all books related to their searches, the recommender provides the user with a tool allowing the user to become aware of relevant items within the library that he may not have selected to actually search for. The recommender provides the user with a notification that he or she has moved towards a location with relevant book available.

In testing the application, users did not see this feature as a disruptive task in searching for a book, but instead found it to be useful. The users immediately became aware when a book related to their search was near them. User tests suggested that because the notification implied the location of a relevant item and information, they were inclined to go further and locate it. After locating the item, users claimed that interruption did not cause them to lose focus in their primary objective and continued original navigation. Below is a table which summarizes the evaluation results.

Table 1. Evaluation Results.

Problem	Evaluation Results
Ease of searching methods (current search tasks are tedious and lead user though multiple screen before obtaining relevant information).	Simplistic and efficient search keeps users focused on primary task (book searching) without adding overhead created with more advanced searches.
Navigation of available resources	Displaying pathway directions and information lead to efficient and more direct navigation and low levels of interruption to user.
Searches yield too much information from feedback to process and decipher everything.	Recommender alleviates this issue with a notification when near a closely related artifacts of search. Low interruption notification still keeps user focused on primary task.

5. CONCLUSIONS AND FUTURE WORK

Our primary goal for this system was to create a location-based tracking system that could serve as an alternative method to traditional library searching. In general, time and effort involved for resource finding and navigation indoors on handheld devices can be minimized through these techniques and strategies:

- Simplistic searching and result listing methods to keep users focused on primary task.
- Searching integrated with map layout and directions provided lead to efficient navigation and low levels of interruption.
- Recommender allows users to search without having to catalog a large number of resources in their own memory. Further simplifies searching process and makes navigating to resources more efficient.

We have found traditional library methods to be time-consuming and rather daunting to patrons who are not that familiar with the library or do not know how the building is organized. Much time is wasted searching through the floors and stacks in often confused, unguided navigation Through user testing and further evaluation, we felt that the Newman Project application met the requirements of its initial desired effects. We set out to develop a library application for a handheld system that would be simplistic, efficient, and easy to use. In order to achieve this goal, we

focused on creating a location-based application with a minimal amount of interruption; one that would not require a user to shift focus completely on the application itself, but allow the user to interact more with his or her environment. By allowing the users to be more interactive with the library itself, we also create a system with high reaction and comprehension. When the users identify their location on map and path to the location of their search results, we want them to be immediately aware of where they are and where they need to go.

In the future, we hope to build more on the concepts and ideas of this application. One addition to be investigated is through exploring the current method of navigating the environment with a drawn out path. This technique can be improved upon dramatically perhaps if we were to allow paths to become dynamic, as opposed to the static methods currently used. In the event that a user becomes lost in navigation, a new path could simply be drawn based on his or her new location. We would also like to explore the idea of allowing a user to essentially create his or her own personalized searches. For instance, if we can distinguish between a researcher and someone who just wants to use the library to study quietly, the application should be able to only display areas of the library that may be relevant to these different types of users. A final area of future work we plan on conducting is going further into detail in refining the current method of pin-pointing books and resources within an indoor environment. With the use of RFID tags, we could attach them to specific resources, allowing us to further narrow down searching and pin-point artifacts to more accurate and precise locations.

Aside from future work being done to the application itself, we also see this as an application which could be extended towards a wider area of uses. For instance, this indoor navigation and searching system could essentially be applied towards indoor product locating in warehouses and department stores and other similar facilities.

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