Enabling Locative Experiences

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ABSTRACT

The appropriate framework to capture and share location information with mobile applications enable the development of interfaces and interface techniques that empower users to obtain and share information on the go. As such, the work in this thesis makes two major contributions. First is the SeeVT framework, a locative backbone that uses currently-available data and equipment in the Virginia Tech and Blacksburg VA environments (e.g., wireless signal triangulation, GPS signals) to make available to applications the location of the device in use. Applications built on this framework have available knowledge of the region in which the user's device is located. Second is a set of four applications built on the SeeVT framework: *SeeVT – Alumni Edition* (a guide for alumni returning to campus, often after lengthy absences), the *Newman Project* (a library information system for finding books and other library resources), *VTAssist* (a information sharing system for disabled users), and *SeeVT-Art* (a guide for users in our local inn and conference center to learn about the art on display). Key in this contribution is our identification and discussion of three interface techniques that emerged from our development efforts: an images-first presentation of information, a lightweight mobile augmented reality style of interaction, and locative content affordances that provide ways to quickly input focused types of information in mobile situations.

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CHAPTER 1 Introduction

The sustained miniaturization of silicon, digital storage, and wireless communications has pushed computing platforms beyond the traditionally tethered paradigm of our work desks. Coupled with the unprecedented proliferation of the internet, round-the-clock connectivity to information and commerce is a reality. This has transformed our understanding and expectations of computing devices, beyond traditional metaphors of information interaction and manipulating the overlap of the physical and virtual worlds. A world where interaction with our physical surroundings is augmented by layers of information from the virtual world. Experiences of friends, historical events, information about commercial and aesthetic experiences in the vicinity, personal opinions, and other information can become explicit—with the appropriate methods of information display and interaction.

Such unprecedented capabilities and platforms present us with challenges and opportunities. This thesis addresses user interface challenges associated with our mobility—challenges in presenting location-relevant information to users in a way that enhances their well-being and the well-being of their community. Given the current and emerging state of technology, it is unreasonable to expect that users wait until they are at a fixed location (i.e., not mobile) before they gain and share information, opinions, and thoughts. We call such interfaces *locative systems*—systems that have available knowledge of the device holder's location.

Building on this basis, the thesis statement can be stated as follows:

> *The appropriate framework to capture and share location information with mobile applications enables the development of interfaces and interface techniques that empower users to obtain and share information on the go.*

Following from this thesis statement, the work in this thesis makes two major contributions. First is the SeeVT framework, a locative backbone that uses currently-available data and equipment in the Virginia Tech and Blacksburg VA environments (e.g., wireless signal triangulation, GPS signals) to make available to applications the location of the device in use. Applications built on this framework have available knowledge of the region in which the user's device is located. Second is a set of four applications built on the SeeVT framework: *SeeVT – Alumni Edition* (a guide for alumni returning to campus, often after lengthy absences), the *Newman Project* (a library information system for finding books and other library resources), *VTAssist* (a information sharing system for disabled users), and *SeeVT-Art* (a guide for users in our local inn and conference center to learn about the art on display). Key in this contribution is our identification and discussion of three interface techniques that emerged from our development efforts: an *images-first* presentation of information, a *lightweight mobile augmented reality* style of interaction, and *locative content affordances* that provide ways to quickly input focused types of information in mobile situations.

This thesis is structured as follows. Chapter 2 presents related work, focusing on both the capabilities that enable locative interfaces and the unique interfaces and interface elements that are emerging in the locative domain. Chapter 3 describes SeeVT, the locative framework established by the author at Virginia Tech that leverages the resources available at our university to enable timely and relevant location determination. Chapter 4 presents locative systems developed on the SeeVT framework, with the author acting as technical lead. Chapter 5 provides a summary of the work and directions for future work.

CHAPTER 2 Related Work

From the early days, navigation has been central to progress. Explorers who set sail to explore the oceans relied on measurements with respect to the positions of celestial bodies. Mathematical and astronomical techniques were used to locate one-self with respect to relatively stationery objects. The use of radio signals proved to be fairly robust and more accurate, leading to the development of one of the first modern methods of navigation during World War II, called LORAN (LOng RAnge Navigation). LORAN laid the foundation of what we know as the Global Positioning System, or GPS (Pace et al., 1995). Primarily commissioned by the United States Department of Defense for military purposes, GPS relies on 24 satellites that revolve around the Earth to provide precision location information in three dimensions. By relying on signals simultaneously received by four satellites, GPS provides much higher precision than previous techniques. GPS navigation is used in a wide range of applications from in-car navigation, to Geographic Information System (GIS)-mapping, to laser-guided bombs.

GPS has become the standard for outdoor location-awareness as it provides feedback in a familiar measurement metric. Information systems like in-car navigators have adopted GPS as the standard for obtaining location, since it requires little or no additional infrastructure deployments and operates worldwide. However, GPS has great difficulty in predicting location in dense urban areas, as also indoors, due to signal fading when they travel through buildings and other structures. With an accuracy of about 100 meters (Pace et al., 1995), using GPS for indoor location determination does not provide the necessary resolution. Along with poor lateral accuracy, GPS cannot make altitude distinctions of three to four meters—the average height of a story in a building—thus making it hard to pin point location, e.g., whether a device is on the first floor or on the second floor. Despite continued progress through technological enhancements, GPS has not yet evolved sufficiently to accommodate the consumer information-technology space. This chapter primarily focuses on technologies making inroads for indoor location determination.

2.1 Locative technology alternatives

While GPS has clear advantages in outdoor location determination, there have been other efforts focused around the use of sensors and sensing equipment to determine location within buildings and in urban areas. The Active Badges research project was one of the earliest efforts at indoor location determination (Want et al., 1992). Active Badges rely on users carrying badges which intermittently emit infrared signals that may be intercepted by a network of embedded sensors in and around the building. Despite concerns about badge size and sensor deployment costs, this and other early efforts inspired designers to think about the possibilities of information systems that could utilize location-information to infer the context of the user, or simply the context of use. One notable related project is MIT's Cricket location system, which involved easy-to-install motes that acted as beepers instead of as a sensor network (Priyantha, Chakraborty, and Balakrishnan, 2000). The user device would identify location based on the signals received from the motes rather than requiring a broadcast from a personal device. Cricket was meant to be easy to deploy, pervasive and privacy observant. However, solutions like Cricket require deployment of a dense sensor network—reasonable for some situations, but lacking the ubiquity necessary to be an inexpensive, widely available, easy-to-implement solution.

To provide a ubiquitous platform, using existing signals could provide a turnkey solution—many of which are created for other purposes, but may be used to determine location and context. For example: mobile phone towers, IEEE 802.11 wireless access points (Wi-Fi), and fixed Bluetooth devices, all broadcast signals that have identification information associated with them. By using these data, combined with triangulation algorithms – similar to those used by GPS, the location of a device can be estimated. The accuracy of the estimation is relative to the number, and strength of the signals that are detected, and since one would expect that more “interesting” places would have more signals, accuracy would be greatest at these places—hence providing best accuracy at the most important places. Place Lab is one such solution that embraces the use of pre-existing signals to obtain location information (LaMarca et al., 2005). Using signals broadcast by GSM, Wi-Fi, and Bluetooth; Place Lab allows the designer to determine client location information indoors or outdoors. The initiative also depends on the user community to contribute by collecting radio environment signatures from around the world to build a central repository of signal vectors. Any client device using Place Lab can download and share the signal vectors for its relevant geography—requiring little or no infrastructure deployment. Place Lab provides a location awareness accuracy of approximately 20 meters.

Our work focuses specifically on the use of Wi-Fi access networks, seeking to categorize the benefits according to the level of access and the amount of information available in the physical space. We propose three categories of indoor location determination techniques: *sniffing* of signals in the environment, *web-services access* to obtain information specific to the area, and *smart algorithms* that take advantage of other information available on mobile devices. In the remainder of this chapter, we describe these techniques in more detail, and we discuss how these techniques have been implemented and used in our framework, called SeeVT using our Agile Usability development process.

2.2 Developing Interfaces for Locative Technologies

Information technologies that utilize knowledge of 'location' to automate adapt or personalize their features and capabilities are known as location-based-systems, or locative systems. Of particular interest in this thesis is the development of interfaces that make use of locative systems and technologies. A broad example would be an interface to communicate online weather information that analyzes a user's IP address to guess their zip code and can automate the presentation of local weather information—perhaps presented in the tool tray of the laptop, regardless of location, without requiring the user to update it. These systems are part of the larger domain of context-aware computing, and possess several interesting research questions. When analyzing the location-awareness needs of information-systems, it is clear that the pursuit is not raw location itself. As with any information system, there are several layers of data that enrich the basic knowledge of the user's location itself. This is where we see the need for trans-coding conventional repositories of information to include the context of location.

Such a transformation requires the integrating of mobile applications with appropriate location-sensing technologies. These can be broken down into two classes: indoor and outdoor. Indoor techniques are generally for used context-aware applications, whereas outdoor techniques are largely used for way-finding and scenarios such as local search. Both of these categories of location awareness have several technological solutions to enable themselves, however we have yet to find a unified framework for ubiquitous location awareness. The biggest reason for the absence of such a platform is that location awareness applications have been historically built in silos: for specific platforms or applications. To allow a larger community of developers to create location-based technologies, the need of the hour is a ubiquitous platform that provides an abstraction of sensing techniques.

An emerging class of location aware applications, called locative interfaces, is of specific interest to us. These are systems that intend to manage attention-utility tradeoffs of mobile-on-the-go interfaces. With the intention of optimizing utility, these systems focus on delivering timely notifications to inform the user of relevant information in his environment. Designing these novel interfaces while balancing critical notification systems parameters of interruption, reaction and comprehension presents new challenges (McCrickard & Chewar, 2003; McCrickard et al., 2003).

When analyzing location awareness, it is clear that the goal is not just to obtain the location itself, but information associated with the location—eventually leading to full context awareness to include people and events in the space, as described in (Dey, 2001). For example, indoor location awareness attributes such as the name of the building, the floor, surrounding environments, and other specific information attributed with the space are of particular interest to designers. Designers of systems intended to support location awareness benefit not only from location accuracy, but also from the metadata (tailored to the current level of location accuracy) that affords several types of cross-interpretations and interpolations of location and other context as well.

Access to this information can be stored with the program, given sufficient computing power and memory. This approach is reasonable for small areas that change infrequently—a library or a nature walk could be examples. Information about the area can be made accessible within the application with low memory requirements and rapid information lookup. However, changes to the information require updates to the data, a potentially intolerable cost for areas where location-related changes occur frequently. For example, a reconfigurable office building where the purpose and even the structure of cubicles change frequently would not be well served by a standalone application. Instead, some sort of web-based repository of information would best meet its needs. Taking this model another step, a mobile system could request and gather information from a wide range of sources, integrating it for the user into a complete picture of the location. As an example, a university campus or networked city would benefit from a smart algorithm that integrated indoor and outdoor signals of various types to communicate a maximally complete picture of the user's location.

Of course, each added layer of access comes with additional costs as well. Simple algorithms may sense known signals from the environment (for example, GPS and wireless signals) to determine location without broadcasting presence. However, other solutions described previously might require requesting or broadcasting of information, revealing the location to a server, information source, or rogue presence—potentially resulting in serious violations of privacy and security. The remainder of this section describes the costs and benefits for three types of indoor location determination approaches: sniffing, web services, and smart algorithms.

Sniffing: as the name suggests; sniffing algorithms sense multiple points in a broadcast environment. Further using these points to interpret the location of a device. The radio environment is generally comprised of one or more standard protocols that could be used to interpret location: modern environments include radio signals including Wi-Fi, Bluetooth, microwaves, and a host of other mediums; creating interesting possibilities for location interpolation. Sniffing is also desirable because all location interpolation and calculations are performed on the client device—eliminating the need for a third-party service to perform the analysis and produce results. As mentioned previously, there are some benefits and disadvantages to this approach.

Performing the location determination on the client device eliminates the need for potentially slow information exchange over a network. This approach gives designers the flexibility they need in order to perform quick and responsive changes to the interfaces as well as decision matrices within their applications. For example, a mobile device with a slow processor and limited memory will need a highly efficient implementation to achieve a speedy analysis. A limiting factor for this approach is the caching of previously known radio vectors. Since most analysis algorithms require a large pool of previously recorded radio-signal vectors to interpolate location, it translates into large volumes of data being pre-cached on the client device. A partial solution for this exists already, pre-caching only for regions that the user is most likely to encounter or visit. Though this is not a complete solution to the resource crunch, it is a reasonable approach for certain situations, with periodic updates or fetches when radio-vectors are upgraded or the system encounters an unknown location.

Herecast is an example of a system using the sniffing model (Paciga and Lutfiyya, 2005). It maintains a central database of known radio vectors, which are then published to client devices on a periodic basis. The clients are programmed to cache only a few known locations that the user has encountered, and relies largely on user participation to enter accurate location information when they enter new areas that the system has not encountered before. The accuracy for these systems is generally acceptable, but there is always the worry of not having a cache of an area that the application is about to encounter. The lack of linking to a service also means that other contextual information associated with the location is hard to integrate with this approach due to device caching constraints and metadata volatility.

Web-services model. Keeping with the fundamental idea of mobile devices facing a resource crunch, this approach has client devices and applications use a central service for location determination. This means that the client device simply measures or "sees" the radio environment and reports it to the central service. The service then performs the necessary computation to interpolate the user location (potentially including other timely information) and communicates it back to the client. This also allows the client to store a minimal amount of data locally and to perform only the simplest of operations—important for mobile devices that often trade off their small size for minimal resources.

The approach is elegant in many ways, but faces several challenges in its simplistic approach such as the problem of network latency leading to lengthy times to perform the transactions. However, as the speed and pervasiveness of mobile networks is on the rise, as is the capabilities of silicon integration technologies for mobile platforms, designing large-scale centralized systems based on the web-services model will be a reasonable approach for many situations. Mobile online applications such as Friend Finders and child tracking services for parents are classic examples of tools that require central services to allow beneficial functionality to the end user.

Smart algorithms. Looking ahead, algorithms that span large and diverse geographic areas will require the integration of many signals, information requests, and additional inputs. Place Lab attempts to address this issue for all radio signals (LaMarca et al., 2005). Currently it can compute location using mobile phone tower signals, Wi-Fi, fixed Bluetooth devices, and GPS. However, we expect that other information will be used for location determination in the near future. For example, the ARDEX project at Virginia Tech seeks to use cameras—quickly becoming commonplace on mobile devices—to create a real-time fiducial-based system for location determination based on augmented reality algorithms (Jacobs, Velez, and Gabbard, 2007). The goal of the system is to integrate it with SeeVT such that anyone at defined hot spots can take a picture of their surrounding area and obtain information about their location. In an interesting twist on this approach, the GumSpots positioning system allows users to take a picture of the gum spots on the ground in urban areas and performs image recognition on them to return user location (Kaufman and Sears, 2006). Other information recording devices could be used in similar ways to help determine or enhance the understanding of our current location.

Chapter 3 Framework for Locative Interfaces

Accurate location determination is the founding stone for building effective locative interfaces. As discussed in the related works sections, the history of location determination has been varied, and the use of location as a parameter in information technology is a relatively recent phenomenon. The diversity of location determination techniques and varied mobile computing platforms present unique sets of challenges to application developers. How does one write an application that adapts to these variances?

The key concerns from an application and interaction designer's point-of-view are:

- Accurate location determination – consistent resolution of location determination.
- Stream of location data – reliable location sensing, irrespective of whether users are indoors, outdoors or in between.
- Unified application development middleware – consolidated software development libraries, and deployment toolkits that reduce the cost and complexity of developing locative apps across computing platforms (mobile, desktop, kiosks).
- Using locative information in traditional information systems – how will websites and other online service use advanced location awareness capabilities?

Furthermore, there are no standard (W3C defined) methods of creating, organizing, and searching through locative content. Early work by the Open Geospatial Consortium (www.ogc.org) is leading the way to address locative content related issues. Mitigating these concerns will have positive implications for the organization, authoring, and consumption of locative content. The implications may not only be relevant to the mobile computing, but to the organization of personal and social content itself.

This chapter begins by identify the high level challenges, and goes onto to suggest solutions alongside outlining our own specific efforts to mitigate these concerns. A summary then provides an overview and a view into future works in locative frameworks.

3.1 Challenges for Locative Application development

Location Determination: There are two fundamental approaches to location determination: a network centric one, and an end-user centric approach. The network based tracking approach implies location tracking intelligence in the internet access network, by way of which the network is able to centrally track and monitor the position of all the devices connected to it. In this case, the end user's computing device does not necessarily require additional hardware to be installed. The end-user centric approach on the other hand, is one where location determination is performed locally by the mobile computing platform. Classic example is an in-car navigation system which relies upon earth roving satellites, and a GPS microchip to interpolate its position in space. The implications of this choice must be made based on considerations of scale, application scenarios and concern for privacy laws. Centralized tracking, as in the case of network based tracking, has a single point of exposure for user location to potentially rogue elements that may misuse this information. Distributed tracking, in the case of the end-user centric architectures, certainly has a higher affordance for selective disclosure of one's location to information systems.

Beyond these architectural differences, the radio technologies used to determine location are varied in nature. For instance, outdoor location sensing is best performed by GPS which is in-turn known to be poor at performing indoor location tracking. On the other hand, there aren't any other scalable techniques for outdoor location sensing. This leads to fragmentation at the heart of locative application design, and presents the need for technologies that allow for smooth handoff from outdoors to the indoors, and vice versa.

Indoor location determination techniques are also fragmented between the various forms of radio signals prevalent in a traditional home and office environment. RFID's, Bluetooth, Wi-Fi, and several other forms of Radio Frequency (RF) have been explored by researchers as possible solutions. Our own implementation of the SeeVT framework utilizes Wi-Fi signals to determine location. The most compelling feature of using Wi-Fi is that it is the medium of choice for wireless internet access in modern homes and offices. This implies ease of adoption where-in little or no additional investment is required to build and determine location indoors. Most other RF media require embedding additional physical infrastructure to emit beacon signals (Bahl & Padmanabhan, 2000). The other requirement for indoor location determination systems is adherence to delivering location in terms of globally understood latitude & longitude.

Another key concern for locative application writers is the *refresh rate of user location*. In other words, how often do the location determination systems respond with an update to user location? The periodicity of these updates is often important for way finding or exploration type applications, whereas certain other applications such as a friend-finder can operate with less frequent updates. Knowledge of the periodicity is essential for planning for fault tolerance and designing failure modes into the experience.

Furthermore, the complexity of dealing with the variations in the location determination hardware & software can be daunting for the average application writer. Each type of location sensing requires special software to interact with drivers, and often has variable refresh rates. To make matters worse, this complexity is compounded exponentially when one considers multiple computing paradigms – mobile, desktop, kiosks et al. Here emerges the need for an abstracted layer of middleware that exposes only essential interfaces and data feeds to enable locative apps. The middleware should handle all the key issues regarding what type of location sensing hardware is available, what is the handoff algorithm, and how often does this data get updated. Irrespective of the architectural model for location tracking (network centric or device centric), the application writer should simply be able to make API style requests to middleware for location data, and worry about higher level interface and interaction issues. No such comprehensive framework exists today.

Moving beyond the application specific implications of locative technologies, as we realize the need to location-enhance traditional websites and web based services, we encounter a newer set of considerations. In addition to issues of trust, there is a larger need for standardizing methods of communicating user location to websites using protocols such as HTTP. Though the solutions to this are beyond the general scope of work of this document, the issues are certainly worth appreciating.

3.2 The SeeVT Locative Framework

Our work on the overarching SeeVT initiative began with the initial effort to determine the location of mobile users indoors. In particular, we developed the SeeVT system to use Wi-Fi signals available throughout the Virginia Tech campus, to determine a mobile terminal's approximate location. A detailed description of this work may be found in (Sampat et al., 2005). Moving beyond just the one location determination methodology our work evolved to include various location sensing, location management, and utilization for creating simple developer tools.

Addressing the issues highlighted in the section above, the core contribution of our SeeVT effort laid at the development of a common framework for enabling locative interfaces. This framework allows app writers to easily develop locative applications through the use of a standard library, and certain web-services to get access to the range of its capabilities. The architecture of the framework is built around the philosophy of extensibility – to support future location sensing, and locative content generation, storage, and distribution.

Figure 1 provides an overview of the various capabilities of the SeeVT framework. As is evident by the modular design of the system, it provides support for various application requirements. Beginning from the right most section, title location feeds: the framework wraps several location sensing techniques. As part of the API support, application writers use a SeeVT library that manages the handoff and allows both architectural variations of location sensing – network centric & device centric. The boxes titled Ekahau, and SeeVT are two network centric approaches accommodated by our design (an extended discussion of these is conducted in section 3.2.2). The GPS feed on the other hand, is an avatar of device centric location sensing. Irrespective of the type of location sensing available, or selected by the application writers; the framework has support for central management & logging of location sensing data. This sort of modularity also allows the application developers to be agnostic of the location sensing method, and focus on the core experience design aspects.

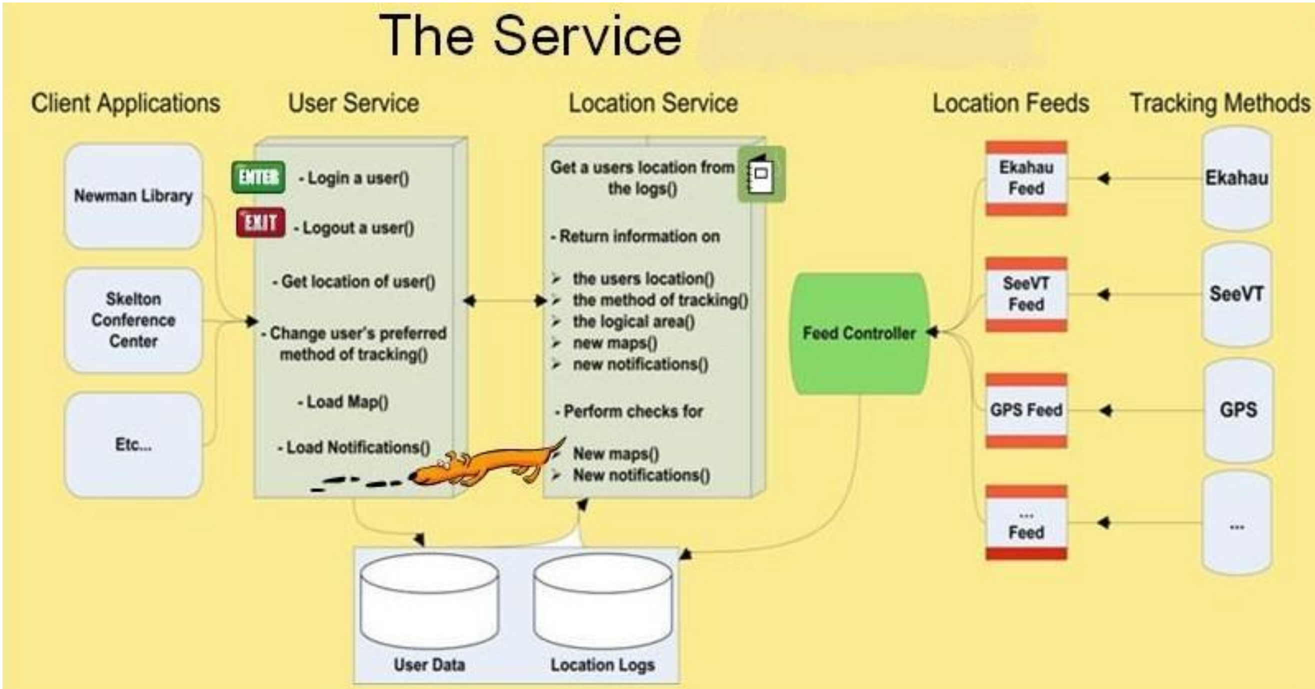
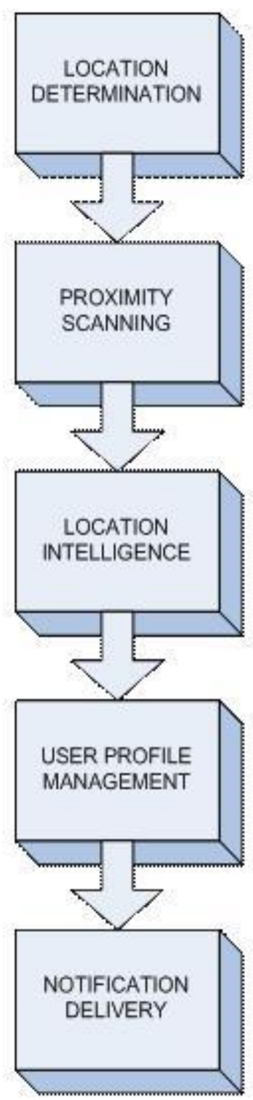


Figure 1 - SeeVT Service Architecture

Moving further left, into the heart of the figure, one notices a set of two services with API support. The location service provides contextual data to the applications, along with allowing the application developers to contribute their own locative content. For example, in the case of a resource finding locative app – such as The Newman Project, app writers need to tie locative context to standard resource listings for printers and copiers in a library. Such that when a user is looking for a printer, the resource is already defined with the same geo-standard as the location sensing data. This reduces costly transcoding procedures associated with bridging data from one format to another for performing search. Advanced centralized services, such as authentication, logging and syndication are also programmed into the framework at the user level. Moving furthest left, we have applications designed by developers that are depicted as utilizing the features of the framework.

3.3 Developing a Locative Application

Location Determination, Proximity Scanning, Location-Intelligence, Profile management and Notification delivery, are the pivotal characteristics of a LBNS. Location Determination begins with a RF scan of the environment—since SeeVT uses the Wi-Fi® medium—we perform a scan for the 'visible' access points in the area. This information is then sent to the location determination agent to interpolate the actual position of the user.



The next stage of the process is to analyze the artifacts in and around the user's current location. This process is conducted by the proximity scanning module of the design shown in Figure 1. This highlights things such as rooms, labs, exits, restrooms etc. considering the campus tour scenario. The remaining modules of the system are the ones that introduce the real customization for each user category. The Location Intelligence module processes various types of attributes about the user's location. This would include functionalities to serve a user GIS enabled maps, or even service level functionality such as real-time tracking of the user. Location Intelligence module also facilitates access to information specific to that location.

Given the very real-time nature of applications built around a user's location, we believe that customizing the information served up to user is highly critical. The user-profile management module aims at solving this issue. It categorizes users into various groups and allows for unique policies to be administered for each group. For example, a soccer mom visiting her son's prospective university might not be interested in knowing what's going on at the supercomputing centre; whereas a prospective graduate student would definitely want to know a lot about such artifacts in his environment. To service this audience we believe that customization of the information is crucial. It also contributes toward the elimination of spam messages being sent to users while they are *roaming*. After having customized the notification messages to the user's specific user group, it is critical to send the message across to the user while they are still in the same context.

Several techniques are present for large-scale message transmission. In the case of large scale systems such as these, Publish-Subscribe systems are the ones that are widely used by the industry. In a publish-subscribe system messages are sent on the common media for all the clients concerned. The client on the user end subscribes or listens only for a specific type & number of messages that it is subscribed to. Subscriptions can be controlled as per the profile of the user. The other critical issue here is the ability to deliver these notifications while the user is still present in the current context. Notifying the user about something on level 1 while he has already moved to level 2 is not going to serve the best interest of the system and the end-user.

3.4 Discussion

This related work section gives insight as to the state-of-the-art in location-aware algorithms, interfaces, and problems. Next, we examine our work on the SeeVT Architecture and how it mitigates these concerns. We describe example applications and scenarios we built on top of this architecture. Future extensibility of this framework will allow us to adapt to new location determination techniques and be an open platform for developing locative applications.

Chapter 4: Example Locative Systems

This chapter describes four systems built on the SeeVT framework. Miten Sampat acted as technical lead for all the efforts, while Jason Chong Lee coordinated the design processes. These systems were *notification systems*, interfaces used in divided attention situations as described in (McCrickard & Chewar, 2003; McCrickard et al., 2003). As such the designers considered user-desired levels of interruption, reaction, and comprehension—often abbreviated as IRC—with the parameters rated on a scale of 0-1. That is, an interface meant to interrupt the user, cause a specific and immediate reaction, but only promote a moderate level of long-term comprehension might have an IRC value of (1, 1, .5).

The system development efforts employed Lee's extreme scenario based design methodology (Lee & McCrickard, 2007), whereby each project team coordinated with a client very regularly and teams delivered functional prototypes at least once every two weeks. This highly-collaborative environment led to significant brainstorming and several ideas were conceptualized and shared. As these development efforts spawned into projects, novel interface techniques began to evolve among them. Three themes particularly of note, described in more depth in the chapter summary at the end, are:

- *Images-first.* Interfaces deliver locative context in the form of pictures or other images to share context, enhance understanding, and evoke memories. This can be contrasted with a 'maps first' approach, which assumes that the primary goal of the user is location-related.
- *Lightweight mobile augmented reality.* Building on the 'images first' approach, mobile AR overlays additional metadata on images, or other visual feeds. Such a

technique allows the interface to draw special attention to specific artifacts in the physical space.

- *Locative content affordances*. Where users have the ability to contribute to social data about a place. The key consideration is the nature of content itself, its affordances for mobile on-the-go manipulation, and sociability.

The core of the chapter summarizes four applications built using the SeeVT platform, listed below. Complete descriptions of each effort are also available in the papers cited; the corresponding sections in this thesis are summaries of these cited papers.

- *Alumni Tour*. Leads visiting alumni to the Virginia Tech campus on a retrospective journey back in time as they autonomously wander around campus. Users are presented with retrospective experiences around their current location, while allowing them to explore opportunistically. This work is featured in (Nair et al., 2006).

- *SeeVT ART*. Better augments art aficionados as they view the Virginia Tech Art collection, hosted at the VT Inn & Skelton Conference Center. This work was part of Scott Kelly's undergraduate thesis, with a paper in preparation. A brief recap of this work can be found in (Lally et al., 2007).

- *The Newman Project*. Used by patrons in a library to better navigate and find resources of interest. It combines useful features that plug into existing library information technologies and provide a valuable aid to navigating. This work appears in (Sciacchitano et al, 2006) and is central to the Master's work of Brian Sciacchitano.

- *VTAssist*. Addresses the needs of physically challenged individuals by providing them location specification information about accessibility, least resistance route planning and a social platform to share experiences. This work appears in (Bhatia et al, 2006).

Finally, the chapter provides a discussion about the various applications and associated information interaction themes that emerged. Discussion also includes usability evaluations and recommendations for feature enhancements.

4.1 Alumni Tour

The passage of time can be symbolized in many different ways. Common methods are to simply have a textual list of events very similar to a timeline, visual representation through the use of graphics and images, sounds, etc. A potent method to show the progression of time is recall. To have a person recollect their living memories and experiences of a particular location is vital in creating a common thread between what they have experienced in the past and what they see in front of them in the present.

Currently, to experience the progression of time one uses things such as yearbooks, university records, diaries, pictures, the internet, and conversations with classmates. What do these resources have in common? All of them have some method of giving cues to recall memories. To be able to help a person recall their memories is the key to bring back fond memories.

When alumni visit their alma mater, they are very interested in the changes that have taken place since they graduated. Many would like to walk around to see the buildings in which they once had classes, recall the many memories they made in the years they spent in this university, and see how the campus has evolved from the time they remember to the present. Often, they are also interested in being able to contribute to the future growth and development of their respective departments and colleges.

Currently when alumni visit the campus, the place may look new and the people are unrecognizable—the information immediately available to the alumni is very much centered on the present. With their five senses, they are able to see, hear, smell, feel and taste the three dimensions that surround them. There is limited opportunity to recall their memories through existing cues.

SeeVT –Alumni Edition is a location-based tour guide system developed specifically for alumni visiting Virginia Tech. The architecture of seeVT –Alumni Edition is based on the existing seeVT framework. The theme is similar to the many smart guides that have emerged in recent years, like Abowd's CyberGuide (Abowd et al., 1997), Volz's Nexus (Volz & Klinec, 1999), and those developed and described by Gupta and Lueg (Gupta & Munson, 2002; Lueg, 2004).

4.1.1 Application Development

To develop a system that would cater well to visiting alumni, we interacted with Ms. Aron Boggs, with the Office of University Relations, who helped us create requirements specific to the target users of this system. Below, we list the main requirements of the seeVT –Alumni Edition.

It was important to specifically cater to our users—the alumni. Alumni are always interested in seeing the different and growing departments on campus. The system should be able to show the different departments at the user's current location. And since alumni are often interested in meeting leaders like the department head, our system should also be able to give information and directions to offices.

To help supplement the alumni tour of the campus, notifications specific to their current location such as labs, offices, and other key places should be provided. This will help the alumni learn more about the location as it is currently exists.

Finally, to incorporate the main idea of the system, evolution of a location over time, a method to present the user with information about a particular location's past, present, and future must be developed. To be able to complete this requirement is one of the main challenges of this system. It is important to develop this feature as this will be adding to the alumni's experience of the tour in a whole different dimension.

4.1.2 Usage Overview

To further explain the use of seeVT –Alumni Edition, included below is an application scenario of how it will be used by alumni visiting the Virginia Tech campus.

Elizabeth, who graduated from Virginia Tech in 1968, with a degree in Computer Science, has returned to visit the campus and see how everything has changed since she graduated so many years ago. She visits the Alumni Center and is given a handheld with the seeVT –Alumni Edition application installed. She is then directed by the staff at the Alumni Center to take a walk around campus and to refer to the seeVT – Alumni Edition if she requires more information or to return to the Alumni Office if she needs further assistance. She starts up the seeVT application and chooses the decade she graduated as 1960-1970 (see Figure 1). Here on, the interface begins to present retrospective images and experiences from the selected era.

Elizabeth then takes a walk to campus and decides to visit McBryde Hall as that is where most of her memories from her life as a student are based. As she reaches the vicinity of McBryde Hall, she is alerted by a gentle knocking sound from her PocketPC. The application informs her that she is in McBryde Hall which houses the Math Department and the Computer Science Department. It also informs her that there are a different number of interesting key points around her current location as well as notes left by other visiting Alumni (see Figure 2). She also notices that there is a button from which she can view a slideshow history of McBryde (see Figure 3).

Elizabeth walks around the building enjoying the sites, while also wondering what happened to the little cabin that used to house the Women's Center behind McBryde during the times she was in school. She looks through the slideshow present on her PocketPC and realizes that it was demolished in 2003 and the Women's Center has now moved to Washington Street on the other side of campus.

She looks through the notes left by other alumni and sees one that was left by a close friend of hers with whom she had lost touch (see Figure 4).

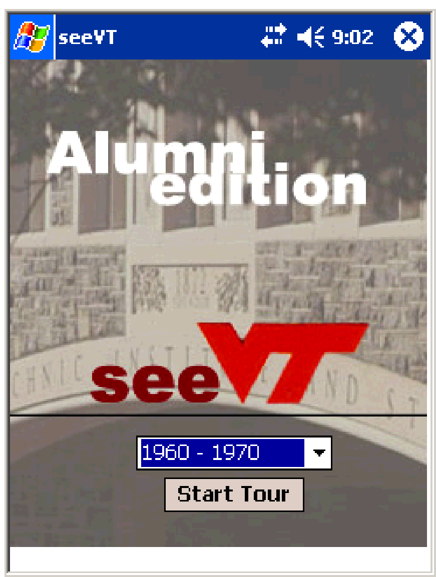


Figure 2: SeeVT Alumni Edition Start Screen

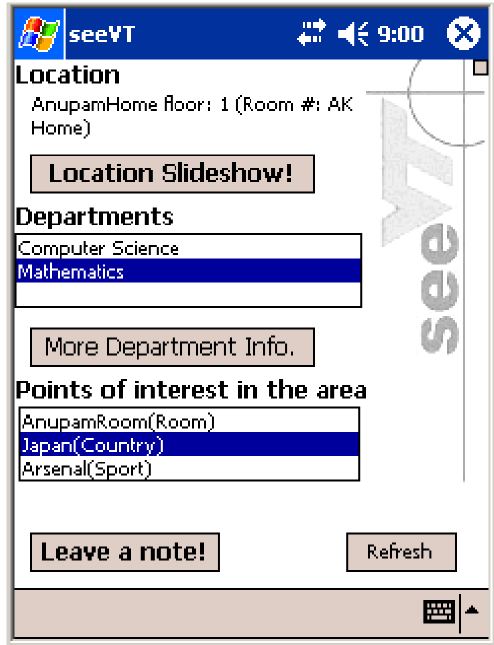


Figure 3: Department List in McBryde Hall

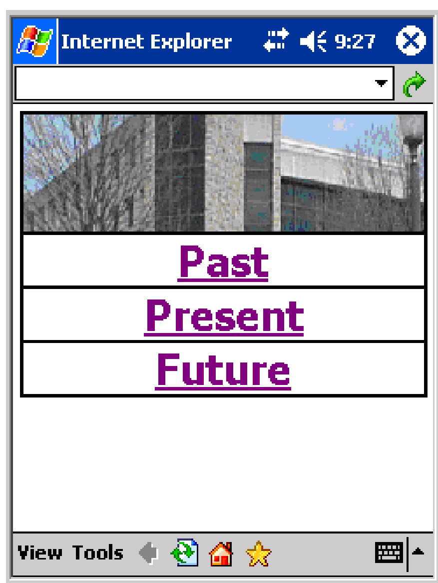


Figure 4: McBryde Hall Slideshow

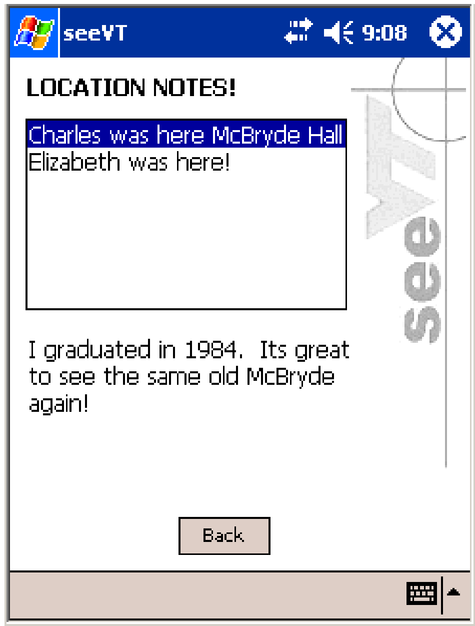


Figure 5: Alumni Notes

This makes her very nostalgic for the times she spent at Virginia Tech and decides she would like to do more to contribute to the growth and development of the school. Again, referring to the seeVT –Alumni Edition application, she looks for more information regarding the Computer Science Department. She finds a button that shows her more information regarding the Department Head of Computer Science. She also clicks on a link to the department website and browses through the different research topics of various students and faculty. She follows the instructions provided by the application to the Department Head's office and is able to meet with the Department Head and discuss how she can contribute to and help further develop the Computer Science Department.

4.1.3 Evaluation

Evaluating the system meant we had to check if the system met the requirements stated earlier. In the evaluation, we tested the system from two different perspectives. The basic testing involved checking the usability of the system as well as the basic requirements.

To test the system, we created a varied set of tasks that would encompass testing all of the features we incorporated into the system. The tasks included finding specific information about a location's history, finding information about particular departments, writing and viewing note tags, and navigating through other key points of interests at a location. We subdivided the tasks into usability tasks and tasks that required the recognition of the essence of time.

In our analytical analysis, we chose to use our domain expert to evaluate the system. Since she dealt with alumni on a regular basis, she was the best hypothetical stakeholder to test the system's usability and feature validity.

We simulated the environment in which the visiting alumni would be in by having the expert come to a building she was not familiar with. Then we gave her a set of tasks she was to complete using only the system. As we did not provide her with any instructions or additional information regarding the use of the system, we were able to see that the application is indeed an intuitive and easy to use system.

The first set of tasks tested the usability of the system where we measured the results in a quantitative manner. These tasks included finding information about the specific location such as: the year the building was built, and the name of the department head. The domain expert rated all these tasks as being very easy to complete and thus validated our attempt to create a highly usable system.

The second set of tasks tested whether the system was able to show the essence of time to the user. This was done through more qualitative feedback questions such as; did finding a note tag left by a former classmate create a sense of nostalgia, and did the slideshow provide a way to visualize the changes that have taken place. These questions provided us with feedback on the effectiveness of the system to instill a sense of nostalgia and belonging to the location.

For system usability, we had to keep in mind the target user class—catering the system to users aged 50 and over. This motivated the design to be easy to use and understand as older alumni might be less familiar with newer technology such as handheld devices. The “walk up and use” characteristic would be vital as many users will not have had prior experience using handheld devices, and probably would be occasional users who never gain great expertise with the interface.

To keep it simple for users to get information, such as department details, we made all the information accessible within a maximum of two button clicks. Having this feature is important because many institutions rely on their alumni for funding and research donations. To make it easy for alumni to find a specific office is high priority. As soon as a user finds out the different departments of a location, he or she is able to get more information on the department, see the department head’s picture, and the directions to his or her office. Keeping this information just a click away is a major goal for the system. By having this information easily accessible and encouraging the alumni to use this feature, the alumni will be more likely to pay the department head a visit. The department head can then explain the needs and goals of the department in more detail to the alumni. The domain expert found this system to be every easy to use even for a novice user.

The feature that gives users the ability to leave note tags on specific locations was an important aspect of the system. The main concern with this system was the ability to write on a handheld device. As inputting text on a handheld device is very different from the input mediums we are normally familiar with, typing note tags was an issue that the domain expert came across. Solving this issue is a bit more involved as the use of the stylus is inherent to handhelds. We could provide a system to leave note tags for a location from a remote desktop computer.

As one of the major attributes of this system, the slideshow feature also had to meet the requirements set forth earlier. As the textual information under images was easy to read, and navigating from one image to the next was also simple, the domain expert rated this feature as being easy to use.

The next phase of our testing involved evaluating the entire system in terms of the sense of time it provided to the user. The two main features we concentrated in this section were the note tagging and the slideshow.

Note tagging is a unique way to connect alums together. When alumni visit, he or she is able to leave and read notes for a particular location. As more and more alumni use the system, a location has the potential of having a note from numerous different users whom they might have shared a lot with during their days as a student. This feature provides a tangible method of dealing with the time that has passed between their graduation and the present.

During our testing, we created a hypothetical note left by a previous visitor to campus. The domain expert felt that notes tagged to locations by alumni who had visited earlier definitely provoked a sense of nostalgia and belonging to the campus community. In testing the slideshow feature, we had the domain expert view the slideshow for the location at which we conducted the testing. This was the main feature in promoting the sense of time through the system. The slideshow provided information about how the building had changed through the decades. This gave the user a unique understanding of the current building with respect to the past and the future. Having this embodied a time capsule type of format which let the user go through pictures where they might get visual cues about the memories and experiences they might have had. We found that a visual timeline of a particular location provided a good method of helping the user reminisce about the time they had spent at the location. A user of the system can view a slideshow of pictures and text of how their location has changed through the years. Dividing this into a past, present, and future sections makes it more relevant and easy to navigate through the interface.

On the whole, the feedback we received was very positive. The domain expert thoroughly enjoyed using the system and was pleased with the information provided. There were a few problems with using the handheld stylus which is inherent to all mobile handheld devices. The amount of real estate available on a handheld's screen was also a downside. But through careful planning and placement of the images and text, we were able to reduce the effects of this constraint.

With respect to time, our domain expert was able to give us very valuable feedback. She stated that our system definitely would reach out to the visiting alumni and provide them a channel to connect the past that they remember, the present that they are experiencing, and the future with respect to their current location. Further, she suggested that we provide the ability to get a bird's eye view of the campus through the changes as this would help further create a feeling of nostalgia as well as allow the visiting alumni to get a broad picture on how the campus has changed as a whole.

Although we have tested our system analytically using a domain expert, empirical data will be vital to validate our research further.

4.1.4 Summary

The Alumni Tour application leads visiting alumni, to the Virginia Tech campus, on a retrospective journey back in time as they autonomously wander around campus. Users are presented with retrospective experiences around their current location, while allowing them to explore opportunistically.

Through the evaluation, we conclude that the system caters elegantly to usability issues, and the general functional requirements. Beyond those basic aspects, we were able to successfully incorporate time as a variant for location-based notification systems. Adding the aspect of the passage of time to location-based applications by incorporating history, as well as the plans for the future to what one can experience at the location today.

Of our key findings, the most significant is the fact that through images and cues we are able to instill a sense of nostalgia in the visiting alumni, our target users. This is important as having a common thread of experience between our classmates and colleague's even decades after one last met them is invaluable. The methods available today to provide a sense of time to locations are very limited in that they present only static information. A yearbook cannot provide you information with what your former classmates are doing now or that the Mathematics Department has moved to the other side of campus. Using a system like seeVT – Alumni Edition provides a more complete picture of how a location has evolved and will continue to evolve.

4.2 SeeVT ART – Skelton Conference Center

On display throughout the world, collections of art can serve to enrich our lives. These collections can be found in a number of venues, including museums, art galleries, and other public spaces. In all of these, visitors come hoping to experience the art collection. Part of that experience is being aware of and understanding information on the pieces viewed. Throughout history, people have attempted to relay the specific, in depth information that users require in a variety of ways. From descriptive placards to human-guided tours, there have been a number of approaches to providing the information needed to maximize a visitor's experience. This has also been a focus of location-aware systems, leading to many digital tour guides.

One such art collection is on display at The Inn at Virginia Tech, Skelton Conference Center, and Holtzman Alumni Center ('the Inn'), one of the most recent additions to the University. On display there is a portion of an extensive art collection, much of which is owned by the Virginia Tech Arts Foundation. Alumni and other guests visiting the Inn may wish to experience the art collection as part of their visit. These visitors would be met with two obstacles on their tour. First, the art collection is currently unlabeled. Second, the collection, over 150 pieces, is distributed throughout the large 3 building complex. We were approached by Ms. Leigh Lally, from the Office of the University Architect with the challenge of designing a system that would overcome these challenges and enhance a user's experience in viewing the art collection.

We approached these challenges with a system utilizing opportunistic navigation (akin to exploring, further defined in section 4.1). In order to display the information required by users, we used a system of targeted multimodal notifications. These notifications are targeted based on the user's present location. Last, in order to create a practical system for real use we developed for a handheld device.

Through our experiences in working with the collection at the Inn, we have developed features which may be extended to other venues. The lessons we learned through designing and testing such a system could be applied to development on a larger scale at a museum or large gallery.

4.2.1 Application Development

We identified two main challenges in enhancing a visitor's experience of the art collection, which can be generalized to any type of art display. The first of these challenges is gathering information on pieces. This includes both basic information such as author, title, or date as well as other information, such as the history or medium of the piece which may help give patrons a more in-depth understanding of the meaning behind a piece. The second challenge is in locating pieces. Users must be able to identify nearby points of interest and they must have a way of navigating the space.

The first challenge was especially prevalent in the Inn as the pieces are currently unlabeled. As a user views a piece, they are presented with no additional information about it. Most users desire to at least be informed of the author's name and the title of the piece. Many would also desire additional information on the piece, such as its date of composure or interesting notes about the piece or author.

The second challenge presents itself in the distribution of the pieces throughout the 3 building complex of the Inn. The complex covers a large amount of ground and contains many rooms and hallways. Strewn throughout this space are the pieces of art which our users are interested in finding. It is easy for people to lose their way or miss certain areas and pieces entirely.

While both of these challenges were identified at the Inn, they are common challenges throughout many museums and art galleries. Labeling is always an issue; viewers desire varying amounts of information which may go beyond the name and title of the piece. However, too much labeling can detract from the piece, as some viewers may not wish to read it. The second challenge also extends to galleries and museums. As the size of a collection becomes large, it becomes increasingly difficult to navigate through it. The goal of our system was to address both of these challenges and design a system which would enable users to overcome them and have a more satisfying experience in touring the art collection.

The Cyberguide project, described in (Abowd et al., 1997), approaches similar challenges. It is a family of systems used to guide people around Georgia Tech and its surroundings. The GUIDE project is another system which guides users around the city of Lancaster. SeeVT-ART differs from these in that it does not require additional infrastructure. Our system leverages the existing wireless internet infrastructure. Also, we explicitly explore the concept of opportunistic navigation as an alternative to the traditional guided tour.

Use of an audio component in such a system is explored in (Bederson, 1995; Oppermann & Specht, 1998). Both papers explore the idea of including audio features and methods of implementing such a feature. Our paper, however, explores how a multimodal interface, including an audio component, can be used to enable opportunistic navigation.

Working with our client, we developed a list of requirements for our system. These included: helping the user find their way around, providing additional information about art pieces, and allowing users to locate specified pieces. Through meetings with our client, we were able to accurately gauge the needs of our target audience: alumni and other guests at the Inn.

4.2.2 Usage Overview

Moving through the design process, we gradually settled on our present approach. Our approach has 3 main features:

- It allows *Opportunistic Navigation*
- It uses *Multimodal Notifications*
- It is *Location Aware*

In order to best address the challenges laid out above, we determined that the ideal method of browsing the space is one that is opportunistic in nature, allowing the user to explore the art at their own pace. This addressed the challenges of navigating the space and locating points of interest. We support the user's need for information through multimodal notifications. In order to provide pertinent information, it was necessary for our system to be aware of its location. Location awareness is integral to our opportunistic approach.

Our system allows the user to engage in opportunistic navigation. This means that we allow users to explore the space on their own, providing relevant information as necessary. This is in contrast to a guided tour. In a guided tour, users are guided along a particular path. Many users, however, would prefer to see the space on their own and create their own experience. Use of opportunistic navigation allows users the freedom to walk around the space at their leisure and see the pieces that are of interest to them. Through this method of navigation, we allow each user to tailor the experience to his or her unique preferences.

Another advantage of using opportunistic navigation is that it does not necessarily interfere with a user's experience. With a guided tour, users are required to constantly check the 'system' (be it a map, a tour guide, or an actual computer system) to ensure that they are on the correct, pre-ordained path. With our system, however, users are free to explore as they

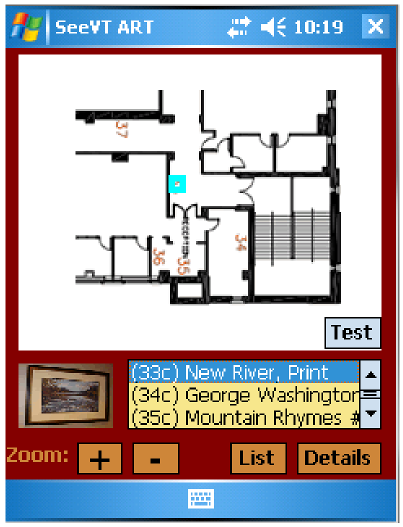


Figure 6: SeeVTART Wayfinding

Figure 7 Lightweight AR

wish, without being constrained by the device. Users can enjoy the environs and reference the device only as they deem necessary.

Opportunistic navigation is not without its downsides. The primary downside is the cognitive burden it sets on the user. Users are required to determine their own route. While this should not be a problem for most users, there are some who would prefer a guided tour. Another downside is that users may miss important pieces. Guided tours can be designed so that all the most important points of interest are hit. With opportunistic navigation, users may accidentally miss important pieces.

We believe that the upsides of opportunistic navigation greatly outweigh the downsides. This is especially true in the environment of the Inn, where the nature of the hallways and building layout lends itself to opportunistic navigation particularly well. Another reason it is particularly well suited to the Inn is that it accommodates 'pick-up' browsing, allowing guests and visitors to pick up a device and begin exploring whenever they wish.

On a grander scale, we believe that opportunistic navigation is well suited for a number of applications. Specific to the art collection space, it is well suited as a method of experiencing the art collection, as it creates an experience uniquely tailored to a user's preferences while providing minimal interruption.

Our use of opportunistic navigation prompted us to design an information interface that would meet the needs of users exploring the space. Users require enough information to be able to discern their location, their surroundings, and where nearby points-of-interest are located. Once users have located a piece they are interested in, they require additional information regarding it. We determined that the best way of handling this was to combine several different types of information display to create a multimodal notification system. Our interface utilizes several visual modes of information display and an audio component.

The visual modes we used are maps, thumbnails, and text. Maps are used for their ability to convey relative location and because they are familiar to most users. Thumbnails are used to add a second layer of authentication to the user's perception of their environment. Use of thumbnails allows a user to confirm that the piece they are near is indeed the piece they see on the device. Thumbnails are also used on the details page to provide context to the detail text. Text is used to provide the additional information on the details page.

Our system design also incorporates an audio component. Use of audio in the details page allows the information to be transferred through a second modality. This is of use to all users, as it allows them to devote their eyes to the piece they are enjoying, as they can listen to the information while viewing a piece.

The notification-system was designed to supplement the user's experience in touring a collection. As we wish for the device to supplement the viewing experience, we aimed to minimize disruptions. Our system dispenses additional information only as requested by the user, allowing them to control the experience without unnecessary interruption from the device.

Our system would not be of any use to users if it did not provide information that was relevant to the user's current surroundings. Thus, it must be aware of its location. This is integral to the concept of the system and the satisfaction of both challenges. This way it can provide information about the pieces which are in the user's general vicinity. Also, making the system location aware allows the system to assist in the navigation of the user by displaying a map to assist opportunistic navigation.

4.2.3 Evaluation

A field study was conducted using the prototype discussed in section 5. For this field study, we recruited participants who were members of our target audience: alumni and other visitors with little or no experience with the Inn or handheld devices. After filling out a background survey to confirm their membership in the target audience, participants were allowed to explore a limited space with the assistance of the device.

Upon completion of the evaluation, users were asked to fill out several subjective questions regarding the effect of the system on their experience. These questions were targeted in order to gather feedback on our use of opportunistic navigation and our multimodal notification system.

Analysis of the user response surveys showed a very positive response. Users were overwhelmingly in favor of being allowed to explore instead of taking a guided tour. Participants reported that the supplemental information provided by the system increased their satisfaction with their experience. One unexpected result of the evaluations was that participants were divided on the amount of attention they devoted to the device. We expected users to only refer to the device when they found a piece they wished to gather further information on. However, a significant portion of users relied on the device to navigate the entire space. Nearly all complaints from the participants were due to the prototype (unfinished) nature of the system.

4.2.4 Summary

SeeVT-Art enables visitors to our local conference center to opportunistically learn about the art that is on display in the halls and rooms. Our interactions with our client and other experts supports opportunistic navigation as an effective way to tour an art gallery. Also, the data indicates that our use of location-based notifications is an effective way of implementing such a manner of navigation. Through our evaluation, we discovered that many users will still rely on the system for their course. Thus any device implemented to make use of opportunistic navigation must support this by balancing presentation of images—which provides context about points of interest in the nearby area—with a map-based overview—which adds the overview of the area that can be important to navigation.

4.3 Newman Library Project

Finding resources in an indoor facility can be a difficult task, especially for patrons who are not that 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. 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.

4.3.1 Application Development

It can be challenging to find items in indoor facilities. Among the challenges of indoor navigation and resource finding are the 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 (Lancaster, 2005). Finding the right book in the least amount of time in such a building can be a daunting task.

The Newman Project, a location-based system, helps users in several ways that we believe would 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 step-by-step 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.

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.

We found that many of the users had concerns with searching; 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.

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.

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 a certain one.

4.3.2 Usage Overview

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.

The Newman Project's built-in searching feature accesses the library database of books using AirPac, a new search system that is currently not available for regular student use. 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 8) (Dijkstra, 1959).

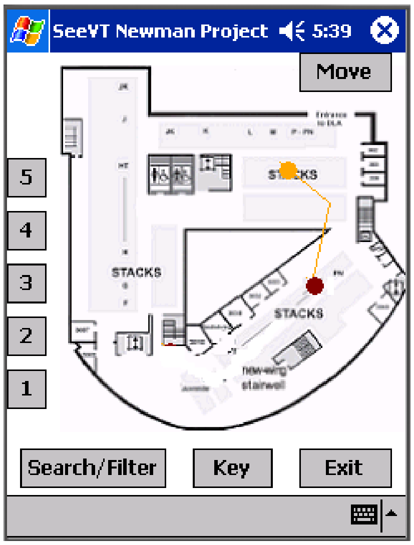


Figure 8: Shortest Path from User to Book

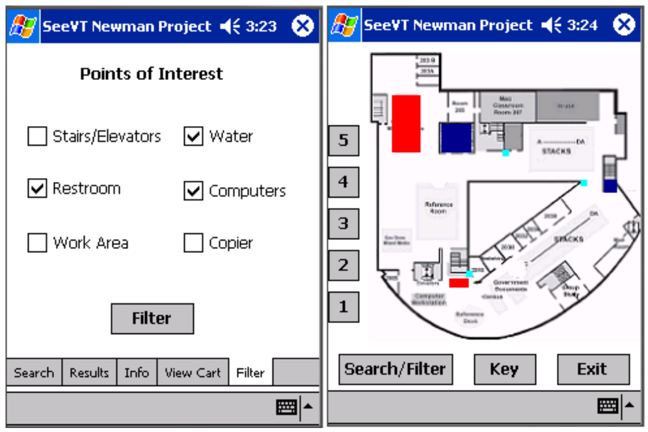


Figure 9: User selected features

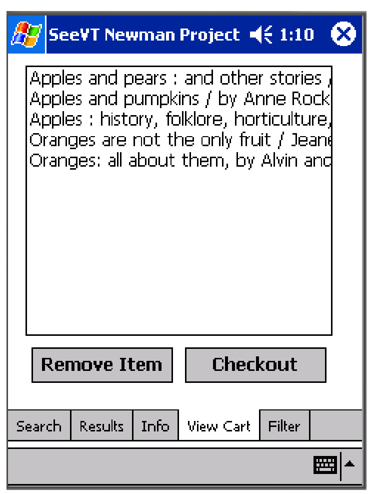


Figure 10: The 'Cart' of User selections

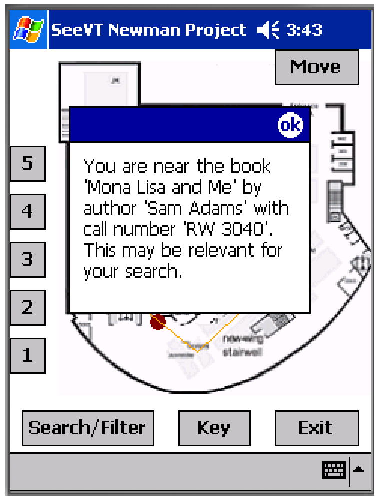


Figure 11: Recommender

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.

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 9). 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.

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.

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 10). 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.

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 11). 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.

4.3.3 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 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.

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.

4.3.4 Summary

The Newman Project is 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.

4.4 VTAssist

Mobile computing technologies are increasingly integrated in our daily lives, providing us with valuable information and services. However, there is a large group of people in our society with disabilities whose needs are not always addressed by present technologies. The U.S Census Department reports that 19.3% of the country's population is disabled; the physically challenged group is the largest disabled group (Waldrop & Stern, 2003). The everyday experience of disabled user groups can be hugely improved by systems that provide assistance specific to their abilities and needs.

Users with mobility impairments often have trouble accessing and navigating through locations because accessibility of those locations can change over time. For instance, an automatic door may malfunction, or a bathroom stall that was previously certified for the handicapped may no longer be accessible due to a newly installed sink. If users are notified about these changes, it improves their ability to safely navigate around locations and buildings.

4.4.1 Application Development

VTAssist was developed to assist users with mobility impairments to better navigate around the Virginia Tech campus by providing location critical information that would assist in planning short trips between and within buildings. This information is provided by coupling 2D maps and a feedback system accessed from a handheld device. Our feedback system is driven by a platform-dependent collaboration from users of the system, who detect infrastructure changes and post it as feedback for the benefit of other users. Notifications are generated from these feedbacks to alert users of location status changes. To view and familiarize with the environment and identify location attributes such as entry/exit and elevator points, we have developed a map feature that displays the location system – a collection of accessible services that a building floor provides.

VTAssist was developed in collaboration with our client: the Assistive Technologies Lab at Virginia Tech, whose interests lie in creating and helping with technologies that are built to provide assistance to the disabled. The Assistive Technologies Lab has a history of sponsoring such research efforts, including a recent effort of a system where people with special needs use laptops that leverage wireless networks to show the location of accessible entrances and facilities relative to current position 0. Our system was evaluated by domain experts to test for usability and assess the value the system features added to users with mobility impairments. Our results are based on responses to user tasks during evaluation.

The field of assistive technologies is certainly rich with many developments that improve the lives of wheelchair users on a global level. However, most of the widely used technological advances providing location-specific information and way finding in location-aware systems for the disabled have been fully integrated into the wheelchair itself, limiting the user pool, and typically do not provide up-to-date information about the accessibility of the location.

Users entering unfamiliar locations need information of their physical environment for navigational support to decide and comprehend accessibility. Most buildings are designed to accommodate users with mobility impairments; however, they do not necessarily provide for all mobility issues. One common issue wheelchair users encounter that arose during the meetings with the Assistive Technologies Lab is the problem of finding correct information on location attributes within the Virginia Tech campus; for example, a door might not be wide enough for wheelchair entry. It is for these reasons that the wheelchair accessible sign does not always indicate a facility accessible to all wheelchair users. It is the objective of the system to notify users with augmented information on these location attributes.

Traditional solutions to location-based mobility assistance have been geared towards short-term navigation, and do not consider the problems of way finding and providing infrastructure information, especially in unfamiliar environments. One such system created in the field was the Smart Wheelchair Component System (SWCS), developed by (Simpson et al., 2004). The SWCS detects obstacles with extra equipment built onto a powered wheelchair and take actions such as arresting movement and decreasing the turning radius. However, it does not provide a viable path, or information on the destination. Systems like the SWCS are not useful if the user can get to a location, but are not able to use the facilities due to lack of up-to-date information. Similar systems, such as the Semi-Autonomous Wheelchair with Helpstar (Uchiyama et al., 2005) provide more information to the user of the surrounding environment, and even present options to the user for navigation. These systems also do not provide information on the infrastructure of the area, or the destination. A good navigational system should incorporate current destination information.

4.4.2 Usage Overview

VTAssist was designed to provide key features to provide location critical information to users with mobility impairments. One of the key problems for this user group is a lack of information on specific areas, or points of interest, on resources within buildings. Change of service status to points of interest could also entail larger problems for users, since they would need to find alternate locations or routes. This would be troublesome since they might need to backtrack toward an alternate location. To avoid these issues, we have added informational features to our system that not only provides static information on points of interest, but also provides notifications in response to feedback.

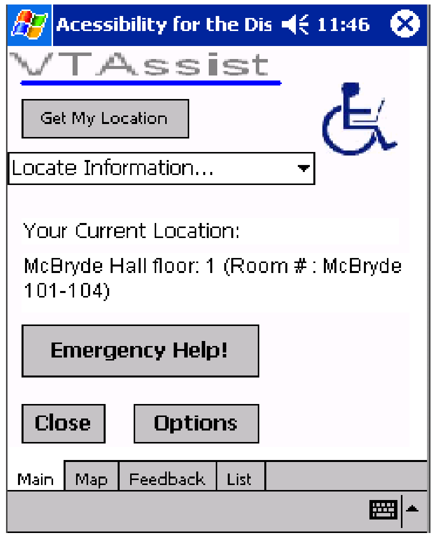


Figure 12: VTAssist - Main Menu

A user entering a new environment often wants to get familiar with their location and to identify accessible services that the location provides. This feature calculates the user's location and provides a map that familiarizes them with the environment. They could also view points of interest by request. Since we are providing familiarization on the locality mainly through the aspects of a map, we wanted the comprehension on the system to be high and the interrupt and reaction to be low.

Environments have various attributes that characterize the location-system. Attributes like entry/exit points, elevators, restrooms, and classrooms are of specific importance to users in a campus building. Users generally familiarize themselves with their environment by meandering through it on a need basis, which usually takes a lot of moving around. This is not the best method to adopt for disabled users, and not a very efficient method for general users. Location information is difficult to convey accurately through dialogue, resulting in ambiguity and misunderstanding.

To save time, energy, and precision, we have facilitated a mapping scheme of building floors on the Virginia Tech campus to be viewed comprehensively on handhelds. When users request to “Get Location” their present location information is taken to pull up the floor map (see Figure 12). This map image is focused to a range of a few rooms, so that the user is able to comprehend his or her present location. To get a more complete feel of the location, the user can scroll around to view the floor and other points of interest (see Figure 13).

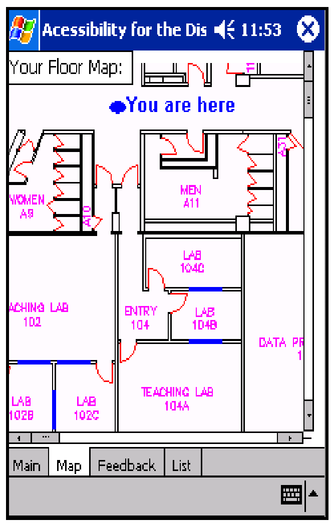


Figure 13: VTAssist Map View

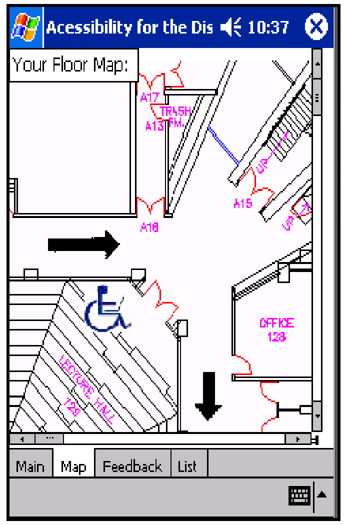


Figure 14: VTAssist WayFinding

The map feature also allows users to view requested points of interest. To do this the user can select the attributes provided by the drop down menu on the main tab. Selecting an attribute displays the point of interest on the map which can be traced back to the user's location with navigational arrows. This not only creates a notion of directional association to the user's present location but also provides the path the user should consider while accessing the location.

To identify attributes that VTAssist presents for users with mobility impairments on a map, we have associated the universal wheelchair accessible sign with rooms that provide wheelchair accessibility. This sign creates a good comprehension of points of interest for our users.

Coupled with the feedback notification features, the system is able to provide comprehensive decision making information for considering accessibility and path movement. Points of interest in a building floor can be very dynamic in its service offerings for users with mobility impairments. To sketch a scenario: a user might be able to access a restroom, but while coming out faces a situation in which he cannot open the door as the automated open button has failed from the inside. These scenarios are not obstacles to regular users, but can create a troublesome situation for disabled users. To prevent users from facing situations while accessing points of interest we have developed a feedback notification system that records changes made to attributes and notifies users of these changes.

The feedback page operates much like a wiki, organized as location-based pages (see Figure 15). As changes are made to the pages, all users subscribed to the page are notified of the change, and are allowed to view the feedback on the location to understand the change, and consider how it affects them.

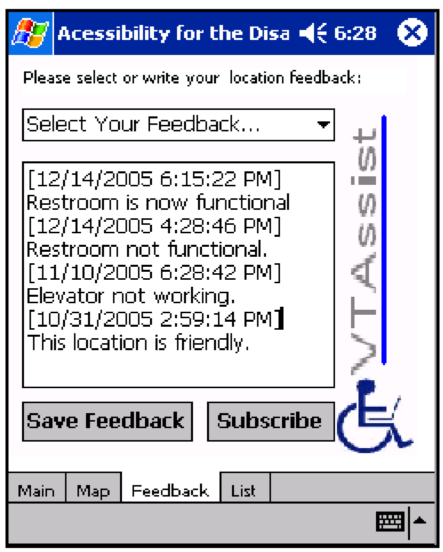


Figure 15: Structure of Locative Wiki

These feedback pages can be edited by any individual present at the location, each change is located with a time stamp on it. The structure of the information can be changed by anyone, but by default it is set to keep the most recent updates at the top. Since it is very important for the feedback system to work on a collaborative basis, we needed to adopt a system that would facilitate users to share information. It has been seen in an open-ended wiki based system that over half the users contribute content (Chau & Maurer, 2005). Success of a system like VTAssist depends on this sort of buy-in, particularly from the disabled community and those who support it.

The feedback offers a decision framework for navigation that, when coupled with aspects of notifications, can be very effective for efficient and helpful accessibility decisions. Users can subscribe to location attributes for notification of changes that are posted (see Figure 4). Any change that is recorded by a user is delivered to users that are subscribed to the attribute. This helps regular or critical users of the attribute to seek alternate locations for services that have been disabled or are in a limited service rendering stage.

Users might want to save and remove their notification subscription on location attributes. This needs to be very quick and easy to manage, since the user's need to track feedback changes on points of interest could be temporary and have a large range. For this purpose, our notifications manger is based on a tree view that we felt could be easily traversed and understood. Many of the attributes act like internal nodes that are superfluous, and trees significantly save space by eliminating the superfluous nodes (Fiala & Greene, 1989).

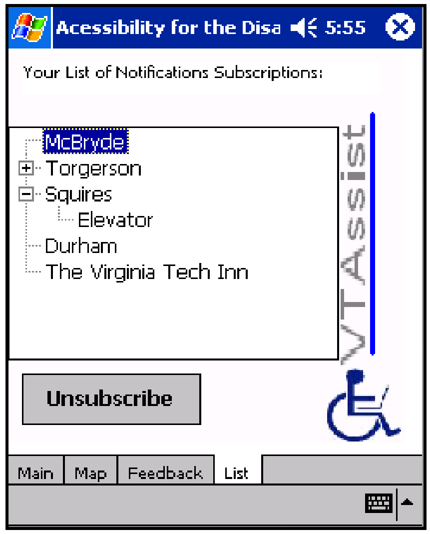


Figure 16: Notifications Subscribed to

Emergency – It is widely noted that during a fire emergency there is a shortage of guidance towards individuals with disabilities. Disabled residents are considered to have the highest death risk (Miller & Beever, 2005). We believe that the feedback notification system can be used to deliver critical information during an evacuation emergency sensitive to the user's location.

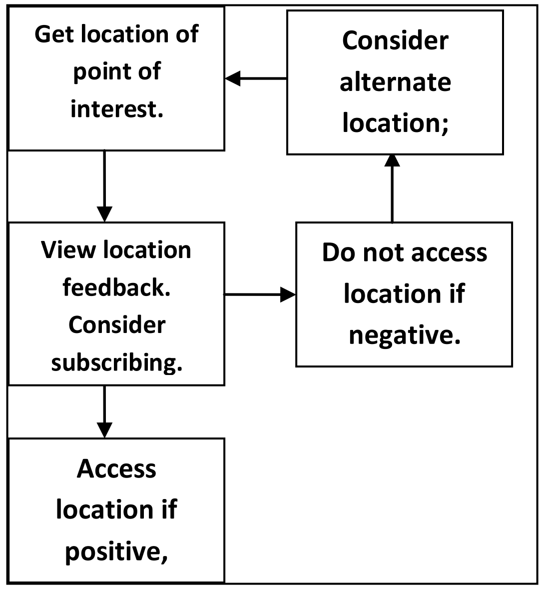


Figure 17: Task Flow sans Notifications

4.4.3 Evaluation

VTAssist was evaluated with the help of two domain experts at the Assistive Technology Lab. The evaluation is based on the responses to our questions derived from tasks that were given to the experts to perform.

Task	Expert Opinion 1 (easy) – 5 (hard)
View Location and feedback	1-2
Post New Feedback	1
Notification Management	1
Notification Comprehension	1
Overall Effectiveness	2-3

Wheelchair user expert opinion on usability

The first task mainly required the user to be able to identify the location and be able to browse the map and get a feel of the environment and seek information by understanding the map or asking the system to identify points of interest; the user would later access the feedback system to decide on accessibility. User results showed that the system could be easily used to identify locations and help familiarize the user with the location system. This was very important since users seeking information on location attributes are largely new to the environment. Results indicated that users will be very comfortable in finding attributes and will be able to associate their current location to the point of interest. This tested the systems ability to help users navigate between points; handheld computing gives the ability to constantly refer to a map for navigation.

The environment mapping feature provided by VTAssist could be used to familiarize and guide users to points of interest. Users reported this was easy to use and helped navigation. Though familiarization and identification was high, users felt the need to be able to zoom in and out of map views, and be able to view locations at a larger scale would be helpful.

Task 1 further required the user to get attribute information from the feedback feature, and use the questionnaire in deciding whether the information helped them make a better decision in accessing the location. This was designed to understand the usability of the feedback system. Results showed that users found the feedback system to be very convenient to access information, this was very important to the feature, since information needs to be structured well, easy to view, and comprehensible.

Since VTAssist is a collaborative system based on the feedback users provide on location attributes, users needed the ability to provide feedback easily and quickly. Task 2 required the user to navigate to a location and find a change in service status that they were required to post to the feedback system. For a quick post we had included a list of service entries that we anticipated users would most likely post. Users found the feedback system very easy to post their messages; this result was promising since the system needs active user posts to be able to generate helpful up to date notifications for all users.

Tasks 3 and 5 were designed to get usability feedback on the notification manager. This is of concern to users that want to monitor varying locations on a daily basis. This feature had extremely positive ratings from users; the tree structure presents attributes specific to their location, and provides an easy way to select and unsubscribe to notifications.

The overall system rating of VTAssist was very promising and the experts felt that the information the system provided was useful in determining their decisions to access locations, and the map assisted in navigation. Experts were concerned about the collaborative dependency of the system, and were worried about the system being up to date. They felt that the system would help users save time and become more efficient. The ability of VTAssist to run on a Tablet PC was recommended, as wheelchair users could navigate while having a larger secondary/supportive view on the Tablet PC.

4.4.4 Summary

VTAssist was an endeavor to create a notification system that provided critical information to mobility-impaired users for accessing locations of interest. The process we have discussed involves understanding the information needs of users with mobility impairments, and turning those needs into a system responsible for gathering and delivering up-to-date location information. We found that the system would be beneficial as a heuristic navigation system. This would need a well integrated mapping system that identifies key locations.

Perhaps most essential in a system like VTAssist is the ability to leverage inputs from users in mobile situations, when and where they encounter an impediment to themselves and/or others. VTAssist accomplishes this with its low effort input features ‘point-and-click’, which are then shared with the large social network of users concerned with the space.

4.5 Discussion

From our experiences working with mobile locative user interfaces, we know that traditional forms of user interaction are often too cumbersome or time consuming. The applications discussed in this chapter demonstrate some of the constraints of applying traditional information interaction metaphors from the desktop computing paradigm, to mobile locative interfaces. This section provides a summarizing discussion of the key findings relating to three usability themes: images first, lightweight mobile augmented reality, and locative content affordances. For each theme, we define the theme, provide examples of its appearance and importance in the SeeVT systems, and describe current and ongoing efforts—both within and outside our lab—where the theme is exemplified.

4.5.1 Images first

We posit that, in many situations, users prefer an *images-first* information display over the traditional context-first interfaces (generally provided with a map), whereby pictures and other images are the first view presented as a user moves into a new location. Representing a break from Shneiderman's mantra—overview first, zoom and filter, details on demand (Shneiderman, 1998)—this finding is a classic example of the need for new interface metaphors. In this case, users were not interested in interfaces that just support wayfinding, but instead are interested in visual information that is tied to place, physically as also contextually. Visual information often conveys several dimensions of context that is relatively difficult to communicate with text. Seeing a picture of an old street where you once lived instantly brings memories of old friends, pranks, and experiences. In mobile on-the-go applications, better utilization of the human minds capabilities of connecting disparate sets of information is vital, thus presenting 'images first' is a valuable methodology.

Furthermore, this approach affords leveraging existing information presentation techniques to derive map-based representations that are meaningful to users' task at hand. Visual cues that are commonly understood, a STOP sign; or a brand logo, can be used to indicate the presence of a known form of content. Just as a hyperlink on a webpage is subtly indicated via a blue highlight and an underline, locative content on map based interfaces can be represented as described. Take for example a marker on a map with a Coca-Cola symbol indicates a vending machine at that location: abstracted views of a physical locality provide virtual representations of conversations, content, and meaning.

Drawing attention back to the SeeVT Alumni Tour application, presentation of retrospective images about a place—instead of the current changed view or a description of how the place used to be 50 years ago—is an exemplar implementation of the images first technique. As visitors meander about the Virginia Tech campus, and stop at points of interest, the interface appropriately use this location determination data to present images from a long gone era. The SeeVT-Art application shows images of the art in the area rather than an annotated map—encouraging users to look around and understand the area where they are located rather than try to understand their position on a map. These types of applications seem particularly appropriate for the small footprint of a handheld and for situations where the users have sufficient understanding of the area but not the history, landmarks, or art. Future work must solidify guidelines and techniques for when 'images first' is the best approach—beginning with the lightweight mobile augmented reality described next.

4.5.2 Lightweight mobile augmented reality

As users move from indoor locations, to outdoor locations, and travel into known "hotspots" or points of interest, the degree to which we can accurately track a mobile user's position and orientation is variable—depending upon the location and surrounding infrastructure. At known hotspots however, there is the possibility of using interface methods that have rigid requirements for accuracy of location detection. Augmented reality (AR)—a wearable headset-based technique of information display that overlays the users' view of the world with information about what the users are seeing—is one such technique. *Lightweight mobile AR* allows the interface to blend the real world with the virtual world through knowledge of precise location, intelligent pattern recognition, orientation, and real-time content overlaying techniques—but replaces the bulky equipment with handhelds or Tablet PCs. The cost is that AR in the true sense is not preserved: users cannot look at the object directly and see information, but must relate information on their handheld to the view around them (typically matching a picture on the handheld with the view around them). Providing a context and content augmented view of the real world using the 'window-to-the-world' metaphor is a promising outcome of the combination of location awareness with other interface/interaction techniques.

Through our work on the SeeVT-ART interface, we used emerging mobile AR techniques developed by Virginia Tech researchers (Jacobs, Velez, and Gabbard, 2006) to augment users with flavor text associated with paintings and sculptures. When users point their camera-enabled mobile devices, the interface overlays flavor text around their perspective view of the artifact. The flavor text is a means to convey contextual information over and above the aesthetics of the art form. Similar to the interactivity of 3D virtual worlds, lightweight mobile AR has the capabilities of enabling pseudo-real world interactions. For examples, one may be able to manipulate virtual avatars using their mobile devices in shared virtual environments.

As we live in a three-dimensional world, with years of experience we are well trained at interacting with physical space (Harrison & Dourish, 1996). Spatial metaphors have been long used by interaction designers to familiarize users to virtual environments (Gaver, 1992). In refashioning our interactions with physical space to afford manipulating/visualizing the locally-prevalent cyberspace we are beginning to enter uncharted territory. Our group believes touch, proximity, and multi-modality are the primary affordances that systems targeted toward this paradigm need to enable. Touch allows the user to manipulate his environment by performing physical gestures: similar to the manner in which the mouse lets one manipulate their computer's desktop screen. In this manner users can interact with the virtual representations and annotations present at that place. Proximity on the other hand is the technological capability of determining the near and immediate virtual environment. It is a mix of hardware and software that is needed to present information that is locally relevant and truly associated with that space. And last but equally important is the multi-modality of the interfaces. In the real world, a human being interacts with this physical environment through voice, visual, and olfactory senses. For the metaphors to be natural and easy to learn: voice and visual forms of interacting must be inherent.

4.5.3 Locative Content Affordances

In this document about location awareness and location based systems, the crucial discussion of the data itself is long overdue. Can data be location aware? What would it mean to have location aware data? For example, can the content have contextual metadata such that it becomes available and present in the appropriate format where it is most likely to be consumed?

Although, this is a much larger question – that is beyond the scope of this effort, it is important to emphasize the crucial role it plays in the scalable development of locative systems. Locative interfaces are often used in constrained, mobile on-the-go scenarios where the attention allocation and physical platforms of information interaction are varied in comparison to the desktop paradigm. The amount of time, and effort expected of a user to author content in such cases has to be carefully designed. The two key affordances for locative/place connected content:

- Low cost (cognitive and computational) input features
- Future extensibility for expansion, updates & distribution (social and private)

Low cost input features imply the affordance where the user has to dedicate minimal attention, effort and cognitive processing to effectively submit his experiences and opinions. As seen in our work on VTAssist, users were able to contribute location connected updates regarding the availability of 'accessible utilities" in the built environment. Given the on-the-go nature of the users, VTAssist has a form style input interface where users select from drop down menus and spend a maximum of two clicks to accomplish their tasks. Similarly, in the Alumni Tour application, leaving notes at a location was created as a Meta widget with a light weight text editor and form-style submission. Finally, the Newman Project focuses all intensive inputs (entering book information) at points when the user would be seated, performing a search, and has as a goal to support more complete integration with the search database.

Chapter 5 Conclusions & Future Work

From our experiences working on mobile location-aware user interfaces, we know that traditional forms of user interaction are often too cumbersome or time consuming. Under the label of the SeeVT framework and architecture—which provides location information based on wireless signal strength—we have built several mobile location-aware interfaces for guiding and informing mobile users. Three key interface techniques stood out from our efforts: an *images first* information presentation technique, a *lightweight mobile augmented reality* interaction style, and *locative interface affordances* for entering data and expressing opinions while on the go.

Future and ongoing directions for this work include the integration of additional location-aware technologies—potentially including RFID, augmented reality hardware and technologies, GPS and wireless cellular signals, and other emerging technologies. The SeeVT framework and applications—in their present and expanding forms—will continue to yield important lessons as to how the technologies will be used in the future. Continued usage of the interfaces will expand our understanding of how people want to make use of locative interfaces. Last but not least, the author plans to continue work in this area at Feeva, a technology company with the goal of transforming broadband network operators into profitable online ad-serving channels—particularly of use to mobile users.

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Vita—Miten Sampat

Education

- **Master of Science**, Computer Science & Applications, **Virginia Tech** – Blacksburg VA, Fall 2007
  GPA – 3.7/4.0
  - Focus on design of Mobile, Location-Aware/Location-Based Systems & Human-Computer Interaction
- **Bachelor of Science**, Computer Science, **Virginia Tech** – Blacksburg VA, Dec 2005
  - Winner, Faculty Choice + People's Choice + Industry Choice, VTURCS Undergraduate Research Symposium
  - Nominated for 2005/06 CRA Outstanding Undergraduate Researcher of the year Award **-** nationwide award (USA)
- **Diploma in Digital Electronics**, Bombay Institute of Technology - Mumbai India, May 2002

Work Experience

- **Feeva Technology Inc**, San Francisco CA **Product Architect** [Summer 2006, consulting at present]
  - Led the design & development of an Internet appliance with an international team of developers
  - Interacted with Venture Capitalists & Consultants during due diligence to raise venture funding
  - Worked closely with VP of Business Development to analyze competitive landscape & outline future product direction
- **Notification Systems Lab**, Department of Computer Science, Virginia Tech. **Researcher** [January 2005 to present]
  - Founded the SeeVT – Locative Projects, exploring Location-Based & Location-Aware Systems design
  - Led group of 20 students, authored 1 Book Chapter & 8 Conference Proceedings Papers
  - Fostered collaborations with several *campus entities*, and brought in Industry interests/partners (Microsoft, SkyHook Wireless)
  - Engineered the underlying architecture and led the development of several prototypes on Windows Mobile Handhelds
  - Currently pursuing a **National Science Foundation** grant of approximately **$1 million** to continue research
- **Reliance Infocomm Limited**, Mumbai, India **Intern – Application Solutions Group** [Summer 2005]
  - Conducted the design & prototyping for R-Search, local-search application for low cost mobile phones [CDMA]
  - Worked closely with mentors at ASG Group to analyze the market requirements for this product

- **F/X Wireless Solutions Pvt Ltd**, Mumbai, India **Business Development Advisor** [Summer 2005]
  - Among the first movers in Consumer Wireless Broadband in India at the time
  - Designed marketing communications, and advised technology acquisition
  - Currently, company is profitable and leading the small business wireless broadband space in Maharashtra, India

Awards & Extra-curricular Activities

- **Program Committee, Where 2.0 2007** - [an O'Reilly Media Conference – May 29-30 2007]
- Participant, Entrepreneurship Competition, **Harvard Business School**, Spring 2006
- Student Competitions Chair, **IEEE Virginia Tech**, 2003
- Winner, BattleBots – Freshman Engineering Robotics Challenge, Virginia Tech, Fall 2002
- Runner-Up, Yantriki – Autonomous Robotics Competition, Techfest 2002, **Indian Inst. Of Technology – Bombay**, April 2002

Other Interests

- Avid reader of Geo-politics, Economics, & Popular Science
- Enjoy sports such as Cricket (Member of the Virginia Tech Cricket Team, 2003 - present), Squash, Soccer