The Creation of a Building Map Application for a University Setting

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A Senior Thesis submitted in partial fulfillment
of the requirements for graduation
in the Honors Program
Liberty University
Spring 2017

Acceptance of Senior Honors Thesis

This Senior Honors Thesis was accepted in partial
fulfillment of the requirements for graduation from the
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Abstract

The use of navigational technology in mobile and web devices has sharply increased in recent years. With the capability to create interactive maps now available, navigating in real time between locations has become possible. This is especially essential in areas and organizations experiencing rapid expansion like Liberty University (LU). Therefore, the author proposes a project to create an interactive map application (IMA) for LU's academic buildings that is scalable and usable through both the university's website and with a mobile application. There are several considerations that must be taken into account when creating the LU map application, such as development methods, platforms, programming languages, software, userbase, and cost. The software development lifecycle is used in order to properly analyze, plan, design, and implement the LU map application. Activity, use-case, and entity-relationship diagrams are used as a basis for the implementation of the application which is created with a user-centric design and security as a priority. Despite some limitations to the LU map application, it provides a preliminary model of how an interactive building map could be used to provide students and faculty new ways to navigate a university setting.

Keywords: map, application, interactivity

The Creation of a Building Map Application for a University Setting

Over the past few years, navigational technology and geographic information systems (GIS) have become an integral part of navigating unfamiliar territories (Kumar & Moore, 2002). One of the areas where navigational technology has yet to become commonplace, however, is the ability to navigate buildings (Ozdenici, Coskun, & Ok, 2015). Mobile and web applications have benefitted heavily from the improvements in navigational technologies and have allowed users to know their location from almost anywhere. Applications such as Google Maps and MapQuest are just a couple of examples of how navigation has improved over the past few years. Navigational technology has even grown to the point to where it is used in games such as Pokémon Go.

Building navigation currently exists, for the most part, in the form of print copies of floor plans. Even if an electronic medium is available, it is generally in the form of a static document or image. These static building maps may be adequate for smaller institutions, but for large or rapidly growing institutions, if these static maps are outdated it can lead to confusion for visitors. A map application that allows for certain user interactivity may prove useful for institutions looking to improve navigation of their campuses, especially for students who are constantly mobile and interactive in the university setting. While consumer navigational technologies might have some limitations in their precision in tracking a user's location in buildings, there are still uses to having a map that has user interactivity. One of the biggest reasons and benefits for a real-time and multi-dimensional navigation map app is to allow users to decide which

part of the building they want to currently view on the map. Therefore, the utilization of systems that allow users to access such information on demand could be ideal.

Web and mobile technologies are ideal platforms when creating a map application as they allow users to interact with the map from almost anywhere. Web and mobile based applications (apps) are ideal due to the overall flexibility these platforms bring when trying to navigate a building. Although a web app allows for greater range of devices to be used when navigating various rooms throughout a building, a mobile app is more resourceful due to the vast number of people with access to smartphones (Smith, 2015).

Liberty University (LU) is a rapidly growing institution that could benefit from an interactive map application (IMA). While there has been exponential growth in LU's use of technology, there is dire need for a dedicated map system for its academic buildings such as DeMoss Hall and Green Hall. Many college students new to a university can feel lost due to being provided with very little guidance in terms of how they can find their classes inside of massive buildings. LU provides basic static maps for its academic buildings, but these maps are difficult to find on the university's website. Furthermore, not all buildings are included on the map due to the ever-changing demographics brought on by so much construction occurring on the growing campus (Liberty University, 2017).

To make matters more complicated, even if there is a map of the buildings, there is very rarely any form of mapping of the interior of the buildings. The design of an IMA of Liberty's major classroom buildings could alleviate many of the problems that students have when navigating inside these buildings, due to their massive size and ever-changing layout. However, security would need to be considered in the design in order to prevent

potential threats to a college campus from having access to the layout of LU's academic buildings (Amat, 2017).

Proposal

The author proposes a project to create an IMA for LU's academic buildings that is scalable and usable through the university's website and a mobile device (smartphone, tablet, laptop, etc.). In designing the IMA specifically for LU's academic buildings, the designer considered the type of developmental software needed, means for implementations, and security risks that could arise from creating such an application. When creating the IMA for LU, observing navigational technology interactions between both users and computing devices was also of the utmost importance. Although the steps and foresight needed to develop an IMA are extensive, the need for better guidance around and within many of Liberty's academic buildings are significant in light of providing a world-class student experience.

Literature Review

The development and creation of an IMA for the various buildings on a college campus require the review of several factors or parts: a) the progression and improvement of accuracy and precision of geographic information systems (GIS) and navigational techniques, b) the interaction of GIS and navigational technologies with users, mobile, and web applications, and c) the exploration of possible solutions and resources for creating a user-friendly IMA.

Improvements in Navigational Systems

Geographic information systems (GIS) and navigational applications have progressed rapidly over the past several years. For example, navigational technologies

have improved through the utilization of user feedback to provide a more accurate means

of location detection (Bhasker, Brown, & Griswold, 2004). Bhasker et al. (2004)

proposed that through the use of wireless access points, users could provide a lower cost

option compared to physical sensors for navigational improvement by identifying various

locations that may not have been discovered or properly mapped. These methods of

navigation improvement were so precise that they even allowed for improvement in

locations that were indoors. Bhasker's, Brown's, & Griswold's, (2004) study provided a

possible consideration that could be potentially used when implementing and improving

upon an IMA.

Another example of the improvements in navigational systems is given by

Cheung (2006) who provides various examples of effective and ineffective techniques in

the process of navigating users throughout a college campus. Cheung studied several user

behaviors to provide an appropriate approach to developing and implementing an ideal

interactive system in wayfinding and navigational technologies. He concluded that a

map-based technique in wayfinding provided some of the best results in terms of

developing a system as compared to image-based or verbal-based techniques. Cheung's

(2006) research gives a great example on how to properly implement an IMA because it

provides several possible and even recommended techniques for developing and

implementing an IMA so that it is easy for students to utilize.

Wilson et al. (2008) conducted a study on how human-computer interaction can

contribute to the improvement of various navigational services. Some techniques utilized

by Wilson et al. (2008) used geocaching and crime data to receive very precise

information about specific locations and identify various behaviors from user

interactions. User behaviors were incorporated into the logic of development for the IMA
to address the flexibility needed for use by various types of people. The building map
application must be able to handle various user behaviors and interactions in order to be
flexible when being used by various types of people.

Ballatore et al. (2010) provide another form of navigational technolgy that
displays the improvements in the field of GIS through RecoMap. RecoMap deduces
various users' interests in order to provide them with relevant geographic and
navigational information. RecoMap is adaptable to the point where it can tell when a
user's location preferences have changed. RecoMap was tested on a college campus
setting and made location recommendations based on the user's current location, as well
as previously recorded information. RecoMap provides a potential implementation of an
IMA as locations that a student may commonly attend can be highlighted on the building
maps of a university.

In a similar vein to RecoMap, Aoidh et al. (2009) proposed several techniques
that allowed for user personalization in navigational technologies. Where as RecoMap
(Ballatore, 2010) focused on navigational technology in all types of devices, Aoidh et al.
focused specifically on how this personalization could be utilized in mobile devices.
zAoidh et al. also proposed several techniques of map personalization including various
user interactions, location based interactions, and location interests based on a user's
profile. The aspect of a user profile being used to personalize navigation is particularly
relevant to Liberty University's map application as it will allow users to have previous or
recommended navigational routes based on their class schedules or preferences.

Interactions in Navigational Systems

Delgado et al. (2009) provide one example of how navigational technologies can possibly interact with mobile devices. They propose that mobile devices can be used to create and navigate building maps. One important facet that Delgado et al. (2009) addresses is the use of network technologies through the phone which allows for the building maps to be more effectively updated. Having up-to-date maps is imperative to the proper implementation of an IMA as this prevents users from becoming disoriented with their current location.

Roth (2013) recommends that developers consider six things when creating an user interactive map:

- What interactions are occuring between the user and the interactive map?

- Why is the interaction being provided to the user?

- When should user interaction occur on an interactive map?

- Who should have access to the various interactions provided by an interactive map?

- Where should the services for an interactive map be provided?

- How should the interactions be provided for users in an interactive?

These questions allow for the proper implementation of an IMA as this will allow for the IMA to have a user-centric design.

Another study of navigational technologies and user interaction was performed by Aoidh et al. (2008), which studied user interests based on their usage of an interactive map. Aoidh et al. utilized a tool called GIViz to analyze various user behaviors when interacting with an interactive map. According to Aoidh et al., the analysis of user

behaviors allows for the interactive map to adapt based on certain behaviors a user displays when utilizing the map.

While user interaction was important to how navigational technologies were created, mobile devices must also be examined when creating a building map application. One study by Herrera, et al. (2009) proposed techniques of tracking traffic data utilizing the GPS features of mobile devices. The reason that mobile devices were chosen for Herrera's, et al. (2009) study was due to the extensive coverage they possessed compared to other Wi-Fi based devices.

Lawson (2012) found that there are ten ways that mobile devices interact with navigational technologies and keep track of a user's location. These navigational technologies include: Global Positioning Systems (GPS), Assisted GPS, Synthetic GPS, Cell ID, Wi-Fi, Inertial Sensors, Barometers, Near Field Communications, Bluetooth Beacons, and Terrestrial Transmitters. According to Lawson, GPS, Wi-Fi, Cellular IDs, and inertial sensors are the most commonly used navigational technologies found in mobile devices.

Park, Hong, & Cho (2007) observed various user interactions through the use of navigational technologies on mobile devices and proposed a map system that was personalized based on user preferences. Park et al. stated that their proposed system would collect various forms of information including locations, time, and weather in order to provide users with a personalized map on their mobile devices. This personalized map would allow users to see places they frequently visited or places that they might like to visit based on their preferences.

Implementation of Navigational Systems

Historically, the implementation of electronically interactive maps to allow users to better navigate college campuses dates to 1998. Hirtle and Sorrows (1998) implemented a multi-modal map that allowed users to utilize the Internet when searching for various locations on their college campus. Hirtle and Sorrows application also utilized the Internet so that users could access various rooms and floors found throughout a building. However, while Hirtle and Sorrows (1998) provided a good basis for the creation of an electronic building map, many of the techniques utilized in their implementation were antiquated by today's standards.

Sataloff, Kaufman, and Levine (2009) developed and implemented an interactive map for the College of Charleston. This campus map was created utilzing a combination of ArcGIS, Adobe Photoshop, and Adobe Illustrator and allowed users to select various parts of the map to view certain pieces of information relating to the campus. Despite this interactivity being useful, this map provided very few ways for users to be directly navigated by the application throughout the various locations on campus.

Cardei, Zankina, Cardei, and Raviv (2013) developed a campus IMA for Google's Android operating system that gave users guidance in navigating college campuses rather than showing their specific location on a map. The campus guidance application utilized the Google Maps API and various web programming languages, such as HTML and JavaScript, in order to guide users around the college campus they were attending. The campus map assistant developed by Cardei et al. was useful for the implementation of an IMA due to the languages that were utilized being well suited for the development of web

and mobile applications. Furthermore, the campus guidance application also provided a potential implementation that could be used in an IMA.

Eder, Nocete, Rances, Tarrosa, and Yanson (2015) provided a similar model for how a campus map should be created in that they suggested using web languages to create a map of a college This particular campus map; however, provided a framework to allow for the creation of maps for buildings through the use of both web languages, such as JavaScript, and database languages, such as MySQL.

One study proposed a unique option to campus navigation that utilized a variation of the game Pac-Man which could provide users with the shortest path to a desired location on their college campus (Wu, Tsai, Wang, & Chuang, 2010). This map used an algorithm to determine the shortest path to a specified location on a campus and allowed users to try and race against a ghost that was trying to get Pac-Man. If the user failed to make it to their desired location by the time the ghost got to Pac-Man, they would lose this variation of the game.

One interesting form of campus navigation was proposed by Griswold et al. (2004) in which users participated in campus navigation by providing a steady flow of feedback regarding their current location. This form of navigation allowed users to identify locations on campus where their peers were located which would provide a basis for campus navigation. While this was a possible option that could be implemented, it was not chosen due to the fact that it could put user safety at risk. Furthermore, community based navigation would be more cumbersome compared to allowing users to actively search for their classes without the assistance from their peers as this requires certain users to have actually visited a specific location.

Han et al. (2014) provided a particularly interesting implementation for an IMA. Han et al. suggested that building maps could be created through the use of wireless access points. Han et. al discussed a seven step process in order to implement the building maps through the use of wireless access points. The seven steps included: analyzing various access points, setting up design goals, drawing the indoor maps, constructing Wi-Fi radio maps, building the system, testing the system, and launching the service while receiving user feedback. Although this study provided a possible solution to how building navigation could be implemented into this project, Wi-fi mapping could not be utilized due to the author's lack of experience in this particular area of expertise, cost, and time constraints. Han (2014) provided insight for the author in regards to how this study could be structured in regards to creating and implementing an IMA of various buildings around a campus setting.

Khan and Syrjarinne (2013) conducted a similar study on creating building maps utilzing Wi-Fi access points. However, the study also suggested utilizing low-cost inertial sensors in order to track user movements. These sensors allowed for real-time tracking of user movements allowing for more precise location tracking on building maps. Computer Aided Drawings (CAD) were also used in the project in order to distinguish between walls and to allow for proper navigation so that directions did not cross over walls and could look for the best possible route. The most valuable part of the project by Khan and Syrjarinne was that the map that was developed could be utlized through the use of a tablet with a dual-core processor. Considering that mobile devices tend to use the same or similar components as tablets, this indicates that this application could be ultilized on most mobile devices with some optimizations.

Wangsiripitak (2014) proposed another method of creating maps for buildings which could be utilized for colleges. Unlike the previous two methods, which utilized the Internet in some capacity, Wangsiripitak suggested the use of cameras when tracking a user's location throughout various buildings. The cameras would track user movement in real-time in order to provide very precise details on their location. Camera-based navigation still appears to be very cumbersome for most users to understand and would not be able to be utilized for this project due to time and cost constraints. Despite this technology being cumbersome, camera-based navigation for various building proves to be an interesting option for possible future research studies in the area of building navigation.

While not necessarily a more efficient way to approach the creation of building maps, Zhi-An and Liang-Qun (2012) proposed the creation of 3D map of various locations throughout a college campus. The 3D map would utilize a combination of WEBGIS and JavaScript in order to provide users with a more effective way to navigate their college campus by allowing them to view their current location and roam the map as they see fit. Furthermore, the use of JavaScript allowed the map to be used on a larger variety of devices. Despite the flexibility involved with Zhi-An and Liang-Qun's project, there were various time and cost constraints that made it an inefficient option when creating an IMA.

A useful resource in the creation of a building map application was w3schools (2016), which provided knowledge on how various web languages could be used in creating a website. One area of knowledge which w3schools provided was the use of the html <map> tag which allowed website designers to specifiy areas on an image that were

clickable (w3schools, 2016). Another area of importance in the creation of a dynamic

web application was PHP. PHP allowed for more dynamic webpages by allowing for

conditional statements, arrays, and the capability to connect to a database (w3schools,

2016). Connecting to a database was important to providing dynamic content as this

allowed for information to be pulled based off of certain user provided information.

MySQL was the ideal database language for PHP as this particular language provides the

best compatability with many PHP functionalities (w3schools, PHP MySQL Database,

2016).

Hostica (2016) provided a helpful platform to host a web based application such

as a building map application. Hostica (2016) allowed users to create websites using

either premade template or allowed users to create websites using their own HTML.

Furthermore, Hostica (2016) allowed for database connection through PHP and allowed

for the creation of a database using MySQL server. Hostica (2016) also has a live chat

that allows users to ask questions should they have issues with their website. As a result,

Hostica (2016) provided the capability to create dynamic websites that could connect to a

database which made it an ideal platform for a building map application.

Another resource that was helpful in the creation of an building map application

was PHP for the Web (Ullman, 2011) particularly in the area of securing a website with

PHP. Ullman (2011) discussed how a programmer could use sessions to protect a website

from having its security compromised. One example of how a website's security could

have been vulnerable without sessions was that a user could have access to secure areas

of the website without login credentials. Sessions should be created when a user logs in

and destroyed when a user logs out in order to prevent potential security issues with a website or web based application.

Methodology

In developing an interactive map application (IMA) to use for the inside of the academic buildings found on Liberty University's (LU) campus, the developer of the IMA considered the development process, the platforms, programming languages and software, the userbase at which the application was directed, and the overall cost of development.

Development Process

One of the first decisions that was made was due to the sheer size of Liberty University: this application would be a proof-of-concept rather than the full map of LU buildings. The author drew on the implementation examples of Hirtle and Sorrows (1998) when developming the LU IMA. This model helped frame the development due to various time and people constraints. As such, this prototype would lend itself to future improvements made possible by a larger development team, time, and money. Furthermore, it was decided that the map application would be built around a database and various design diagrams. Despite being only a prototype, the map application still had a full Systems Development Life Cycle, or SDLC, using the agile development methodology. As a result of the SDLC, there were several diagrams that had to be created for the LU map application during the design phase of creating the application.

Platforms

Initially, it was speculated that developing a mobile application would be the best choice for the creation of a building map for LU due to the convience and portablility of

having a map on a mobile device; however, additional research suggested that using web

technologies would prove to be the better choice for various reasons, but foremost being

that web technologies are used among all types of computing devices, such as computers

and smartphones, and have better flexibility that could allow them to be easily converted

into mobile applications. For example, Lawson (2012) provided various insights into

possible technologies that could be utilized when creating and navigating a user

interactive building map which made it relevant to the author's map application. As a

result of web development's flexability, it was decided that it would be better to create a

website for the Liberty University building maps and then convert the website into a

mobile application after it had been optimized for mobile devices.

Programming Languages

Several web programming languages were considered to properly implement the

IMA for LU. A combination of MySQL and PHP was utilized to create the back-end of

the map application that would store various pieces of information that were necessary

for it to function effectively. MySQL was the language chosen to create the database due

to its overall cost effectiveness, flexibility, and compatability with various types of web

languages. PHP was utilized to communicate with the database as well as output user-

requested information from the MySQL database. PHP was used also to provide various

security capabilities to the website so that database information would not be

compromised.

A combination of HTML, CSS, and JavaScript were used in order to create the

front-end of the IMA for LU. HTML was mainly used to provide user controls such as

text boxes and buttons so that the user could submit and obtain the information they

requested. CSS was used to provide the overall look to the website and allowed the

website to be designed with various types of devices in mind. JavaScript was used to

provide some user feedback as well as to allow for the website to handle various other

conditions that could not be handled by any of the other languages used.

Software

Several software tools were utilized to properly design the IMA for LU's

academic buildings. The designer first used Microsoft Visio to create the activity and use

case diagrams, as well as the visual representation of the LU IMA. Microsoft Visio

provided several tools that allowed for a diagram or map to be created relatively

seamlessly. The designer used ER Assistant to create the Entity-Relationship Diagram

(ERD). ER Assistant was an ideal solution to create an ERD due to its nonexistant cost

and the author's knowledge of how to create an ERD using this program.

After the design of the IMA was completed, software tools were needed in order

to implement LU's IMA. Initially, the database was created and tested using MySQL

Workbench and the database connection with PHP was tested using XAMPP. These

software tools, however, proved to be too limited in that they only allowed for the web

applications to be used on the device on which the application was created.

Finally, it was decided that the web-hosting platform Hostica would be used to

allow for testing to be performed on multiple devices. Hostica has its own MySQL server

that allows for a database to be utilized alongside the website that is currently being

hosted, allowing for quick importing from MySQL workbench. Hostica allows for the LU

IMA website to be tested on multiple devices effectively. Hostica was also utilized due to

the author owning a domain, [www.tylerwhitesell.com,](http://www.tylerwhitesell.com) through Hostica prior to the start

of the development of the map application. Despite Hostica being used to host the website for the IMA for LU, there was a need to convert the website into a mobile application. GoNative allows for the free conversion of a website into mobile iOS and Android applications as long as the applications have not been published to mobile app stores. As this project was intended as a prototype and will only be used for research and testing purposes, GoNative was ideal as it provided an optimal amount of development time that would allow the programmer to create a mobile application assuming the website was properly optimized. Through the combination of Hostica and GoNative, the LU IMA is able to be used on both desktop and mobile devices that have access to the Internet.

Users

The Liberty University map application was designed to be as user-friendly as possible for the intended audience. The questions proposed in the study by Roth (2013) were all considered in the creation of the IMA for LU because knowing the various needs of the users was imperative to making sure the application was performing to the best of its capabilities. The map application also assumed that all users would be able to read English at a basic level of proficiency. The IMA for LU was intended mainly for all students and faculty members; however, because the application was only a prototype, the actual audience for this particular project was a smaller group of approximately ten faculty members and students. As a result, while the map application was designed with students and teachers in mind, it may not be as robust and stable a system as an application that could be developed by multiple software engineers with a larger budget and timeframe.

Cost

As a result of the use of either several open-source pieces of software or software provided for free by LU for students, the cost of the project remains relatively low. The only service cost comes with the use of Hostica which requires that users pay a $55 subscription fee in order to host their websites after the first year of use (Hostica, 2016). Due to the author's familiarity with Hostica, it was decided that the cost was worth more than the time required to learn a cheaper or possibly free web hosting service such as WordPress or Go Daddy. Despite the low cost that was involved in developing the Liberty University map application, costs would have increased greatly if a fully implemented IMA had been developed and published. Licensing fees required for publishing mobile applications that are created by GoNative to an app store range anywhere from $590 to $890 (GoNative, 2016). As a result of these high costs, as well as the prototype nature of this application, it was decided that the map application would go unpublished and instead would be tested on the author's personal mobile devices.

<div align="center">Application Design</div>

The application design phase of software is where components of the systems are broken into smaller programmable pieces. For this project, steps were built to ensure the interaction component with the navigation system. As such, various diagrams were created to properly design the IMA for LU including an activity diagram, a use-case diagram, and an entity-relationship diagram or ERD.

Activity Diagram

The activity diagram addresses the various steps that the user, application, and database will go throughout the standard use of the IMA (see Figure 1). The map

application starts with users logging in with their credentials. Depending on whether or not the username and password are found in the database, the map application either allows or denies the user entry into the application. If the login is successful, the map application sends the user to the building select screen where the user selects which building they want to navigate. Once users select the building, they can either choose the room they want to view on the default floor that is programmed into the application or choose a different floor to navigate. After users select the room they want to view information from, the database matches the room with teacher and classroom information and then displays it on the map application. Users can then exit from the displayed room information whenever they feel like it and then either select another room and view its information or log out from the application. An important piece of information to note from the activity diagram was that users can choose to log out anytime they wish throughout their use of the IMA assuming they were in the portion of the application that requires them to be logged in.
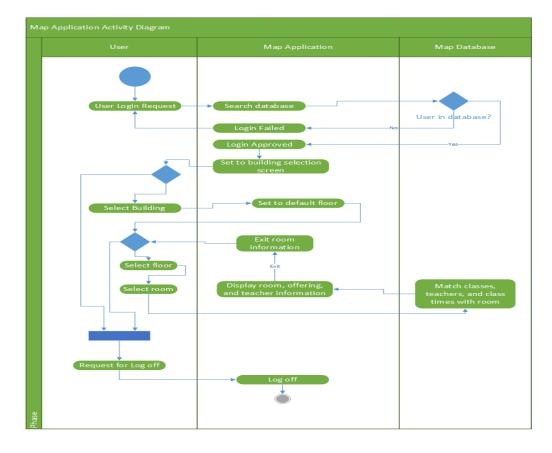
Figure 1. Liberty University building map application activity diagram

Use-case Diagram

A use-case diagram is used to describe the various actions that a user or users may perform throughout use of the IMA for LU. A use-case diagram displays all of the human actors that could be involved throughout the use of the IMA for LU and what actions they can perform. For the Liberty University map application, there is only need for one use-case diagram (see Figure 2). The use-case diagram for the IMA for LU iss relatively simple as there is only one actor, in this case the user, that would be involved throughout the use of the entire map application. The various actions that users can perform throughout their use of the IMA for LU included logging into the application, selecting the building, selecting the floor, selecting the room, and logging out of the application.
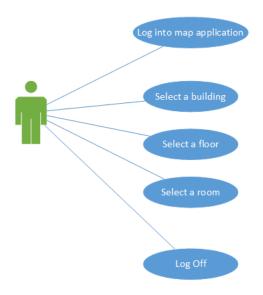
Figure 2. Liberty University building map application use-case diagram.

Entity Relationship Diagram (ERD)

An ERD describes the structure of the various pieces of information that are stored in the back-end database of the IMA for LU (see Figure 3). Some examples of entities that are used throughout the creation of the IMA for LU are a building, student, offering, and class. There are some entities that were not fully utilized in the current version of the map application such as the IDLevel or Staff entities. However, if future research occurs on the IMA for LU these unused entities will be necessary for further improvements. There are several attributes that are used to define the entities that are a part of the map application. Many of these attributes are particularly important to the overall operation of the map application. Some of these attributes include a username and password for the users, building, room, class, and offering numbers, and the teacher and class information for each room.

Relationships are also a highly important aspect of this ERD as they allow for information from different entities to be connected to each other. The only types of relationships that were utilized throughout the creation of the back end of the map

application are one-to-many relationships with either optional or required cardinalities depending on the entities. An example of how optional cardinalities are used on some of the relationships are when teachers can choose not to teach any classes. Some relationships, however, require that both entities be part of one another with many of these being represented in identifying relationships. Identifying relationships are used on many of the relationships because many entities require composite primary keys as they could not exist without a second entity. For example, an offering could not exist without a class, or a room could not exist without a building.

Also, a generalization hierarchy is used due to there being attributes of an overall entity that could be used to describe several sub-entities with different attributes of their own. For example, in the ERD for the IMA database, a person that is able to use the map application has certain attributes such as a first name, username, and email. However, while a student, teacher, and staff member may all have the same attributes as a person, they have different purposes. For example, a student would be enrolled in a class while a teacher would be teaching a class. Furthermore, a generalization hierarchy was neccessary due to the possibility of more attributes being a part of separate entities in a future version or release. As a result of how the entities, attributes, and relationships are structured for LU's IMA, the database was created using the same structure as the ERD.
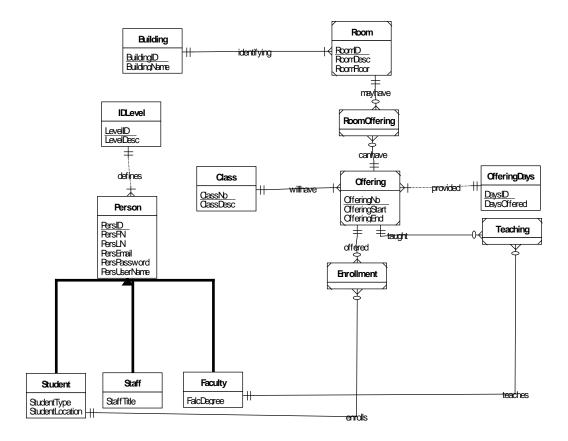
Figure 3. Liberty University building map application entity-relationship diagram.

Application Implementation

Security

Security is an important consideration in the design and implementation of a map application because it prevents potential threats to an organization. For a university, it is important to prevent people who are not students or employees from gaining access to the systems. Security could be breached if unauthorized and potentially dangerous users had access to the layout of academic buildings. Knowing the internal layout of Liberty University's academic buildings could subject the university to possible virtual and physical attacks. The first implementation stage of the IMA for LU is the login page (see Figure 4). The login page allows for the map to be secured from potential threats and unauthorized users.

Another security implementation that is utilized for this IMA is PHP sessions. PHP sessions prevent users that have been logged out or have never logged in from accessing and utilizing the information stored in the IMA. Another use of PHP sessions in the IMA is in the implementation of logging users out after a certain amount of time has passed since their last activitiy. Logging users out after a certain amount of time prevents access to an unattended computer by unauthorized users. In the implementation of the IMA for LU, JavaScript is used to log users out after ten minutes of not moving their cursor. Ten minutes of inactivity was considered an ideal amount of time to log the user out based on how this functionality was observed to be implemented for several websites, including the Liberty University website, that required information to be well secured.
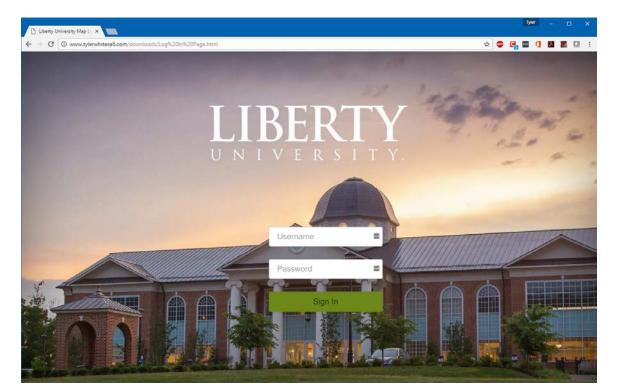

Figure 4. Liberty University building map application login page.

Layout

The layout of how information is presented is highly important when developing

an application because the layout can decide the usablility of an application. The login

page has the username and password textboxes as well as the submit button centered on

the page (see Figure 5). Additionally, the background image on the login page

automatically resizes to the screen. Originally, the layout included a sidebar to allow the

user to select the desired building and floor to navigate; however, the sidebar caused

several issues with the viewability of the map itself on mobile devices, so it was moved

to the top of the page. The map is centered on the page as this is considered the main

content that the user is going to be using. The map is also capable of being resized

through the use of a JavaScript library which is important when optimizing the map

application for mobile devices. JavaScript is also used to provide user feedback in cases

such unsuccessful logins or when a user is logged out of the IMA.

Figure 5. Liberty University building map prototype of the first floor of DeMoss Hall.

A table format is used to display class and teacher information in the IMA (see Figure 6). While a table format may be basic, it proves to be an ideal implementation for making the class and teacher information readable. The table format is ordered from left to right with the most emphasized information being on the left, which would be mainly class information, with the less emphasized information on the right, in this case the information on the professors.

Figure 6. Liberty University building map application prototype of room information.

Testing

While much of the testing for the IMA was performed by the author for this study,

outside sources tested the limitations of the IMA for LU. The IMA for LU was tested

using voluntary students in the age range of 18-23 and faculty members in the

approximate age range of 30-60. Many students and faculty tested to see in what ways the

map application could fail. One error that was discovered from this beta testing was that

the first record of the database was not being read when logging into the map application.

As a result, the source of the first record not being read was found in the IMA's source

code and was subsequently edited and fixed. One student attempted to perform Structure

Query Langugage (SQL) injections to see if he could manipulate and destroy the database

information found on the website. When the SQL injections were performed, they were

rejected by Hostica's security, which showed that this potential security vulnerability had

already been addressed. The students and the faculty members also provided

recommendations as to how the implementation of the map application could be

improved. One example of an improvement that was implemented based on user-

feedback was the currently selected floor being highlighted in order to allow users to better understand their current location.

Discussion & Conclusions

The purpose of this study was to create a framework and start the groundwork for the development of an IMA that could be used in a university setting. As a result, the study was conducted by creating a prototype of an interactive building map application using Liberty University as the host institution. The building map application was created with the intention of being user friendly and robust enough with the potential to be improved upon in future studies. The IMA was necessary because it could allow students to better navigate LU's academic buildings and prevent them from being lost in unfamiliar locations.

Limitations

There was one limitation identified with the creation of the prototype IMA for Liberty University. The original design decisions included a search function that would allow users to search for the room and then the map application would either navigate them to the room or find the room for them either by zooming into the room or highlighting the room. However, this functionality was unable to be implemented due to the time and resource constraints. As a result, the map application prototype was not as interactive as initially envisioned.

Recommendations for Improvement and Future Research

There are some improvements that can be made to the IMA for LU with future releases. First, extremely precise location tracking could be added to track the current location of a user in an academic building. This could allow users to not only know their

current location in a building but also allow navigation to be implemented to allow users

to get from their current location to a desired location. Second, a future release should be

designed with the capability to accommodate for people with disabilities. The prototype

of the IMA for LU assumed that users were physically able to use and read the map

which does not make accommodations for people who have disabilities, restricting their

use of the map (blindness) or providing navigation that does not include handicap

accessible entrances. Possible solutions include providing the ability to have the map

instructions read aloud via the app or making it compatible with specialized software for

those who have disabilities.

There were several proposed improvements from other sources that could be

possibly implemented in future versions of the IMA for LU. First, one recommended

revision to the IMA is the inclusion a component to track user preferences to find

potential areas of interest and make adaptations based on a user's behaviors and most-

used locations (Aoidh et al., 2008). Second, tracking use and popularity of locations

could provide information for prioritizing improvements in certain locations (Herrera, et

al., 2009). Tracking traffic data on the various locations on Liberty University's campus

could provide interesting results as to which areas of campus were more popular than

others, which would allow for higher prioritization of more popular areas when creating

or improving upon the building map application. Third, having various pieces of user

information, such as frequently visited locations being collected while people were using

the IMA for LU, could provide users with suggestions of various locations on a building

map based on their personal preferences (Park, Hong, & Cho, 2007). Finally, future

development of the IMA for the buildings LU should look at using a mobile device that

could provide its own algorithm which would allow for precise navigation to occur

(Delgado, Medina, Ruiz-Lozano, & Vila, 2009).

Conclusion

In conclusion, there were several steps that needed to be performed to create the

Liberty University map application using SDLC. The map application had to be analyzed

and planned to decide what resources and costs were needed for development. Design

was also important to how the Liberty University map application would eventually

operate. The implementation of the Liberty University map application was created with

a user-centric design and security as a priority. In the end, the Liberty University map

application provided an example of a useful tool that could be used to provide students

and faculty new ways to navigate a university setting.

References

Aoidh, E. M., Bertolotto, M., & Wilson, D. C. (2008). Understanding geospatial interests by visualizing map interaction behavior. *Information Visualization*, 7(3-4), 275-286. doi:10.1057/ivs.2008.24

Amat, G. (2017, February 6). *http://osiris-indoor.github.io/news/2017/02/06/Osiris-1_2-brings-security.html*. Retrieved from Osiris: http://osiris-indoor.github.io/news/2017/02/06/Osiris-1_2-brings-security.html

Aoidh, E. M., McArdle, G., Petit, M., Ray, C., Bertolotto, M., Claramunt, C., & Wilson, D. (2009). Personalization in adaptive and interactive GIS. *Annals of GIS*, 23-33.

Ballatore, A., McArdle, G., Kelly, C., & Bertolotto, M. (2010). RecoMap: an interactive and adaptive map-based recommender. *Proceedings of the 2010 ACM Symposium on Applied Computing* (pp. 887-891). New York: ACM.

Bhasker, E. S., Brown, S. W., & Griswold, W. G. (2004). Employing User Feedback for Fast, Accurate, Low-Maintenance Geolocationing. *Proceedings of the Second IEEE Annual Conference on Pervasive Computing and Communications (PERCOM'04)* (pp. 111-120). San Diego: IEEE.

Cardei, M., Zankina, I., Cardei, I., & Raviv, D. (2013). Campus Assistant Application on an Android Platform. *Proceedings of IEEE Southeastcon* (pp. 1-6). Jacksonville: IEEE.

Cheung, A. K. (2006). Representational Issues in Interactive Wayfinding Systems: Navigating the Auckland University Campus . In J. D. Carswell, & T. Tezuka (Eds.), *Web and Wireless Geographical Information Systems* (pp. 90-101). Hong Kong: SpringerLink.

Delgado, M., Medina, J., Ruiz-Lozano, D., & Vila, A. (2009). Semantic building maps in
      mobile devices. *Proceedings of the 4th International Conference on Ubiquitous
      Information Technologies & Applications* (pp. 1-6). Fukuoka: IEEE.

Eder, M. S., Nocete, C. J., Rances, G. L., Tarrosa, E. M., & Yanson, J. N. (2015). Web
      Interactive Campus Map. *International Journal of Scientific & Technology
      Research*, 62-67.

GoNative. (2016, February 2). *Pricing*. Retrieved from GoNative:
      https://gonative.io/pricing

Griswold, W., Shanahan, P., Brown, S., Boyer, R., Ratto, M., Shapiro, R., & Truong, T.
      (2004). ActiveCampus: Experiments in Community-Oriented Ubiquitous
      Computing. *IEEE*, 73-81.

Han, D., Jung, S., Lee, M., & Yoon, G. (2014). Building a Practical Wi-Fi-Based Indoor
      Navigation System. *IEEE Pervasive Computing*, 72 - 79.

Herrera, J. C., Work, D. B., Herring, R., Ban, X., Jacobson, Q., & Bayen, A. M. (2009).
      Evaluation of traffic data obtained via GPS-enabled mobile phones: The Mobile
      Century field experiment. *Transportation Research Part C: Emergining
      Technologies, 18*(2010), 568-583. doi:10.1016/j.trc.2009.10.006

Hirtle, S. C., & Sorrows, M. E. (1998). Designing a Multi-Modal Tool for Locating
      Buildings on a College Campus. *Journal of Environmental Psychology*, 265-276.

Hostica. (2016). *Hostica*. Retrieved from Hostica: https://www.hostica.com/

Hostica. (2016). *Simple Hosting, Simple Pricing*. Retrieved from Hostica:
      https://www.hostica.com/hosting/pricing.html

Khan, M. I., & Syrjarinne, J. (2013). Investigating Effective Methods for Integration of

   Building's Map with Low cost Inertial Sensors and Wifi-based Positioning.

   International Conference on Indoor Positioning and Indoor Navigation (pp. 1-8).

   Montbeliard-Belfort: IEEE.

Kumar, S., & Moore, K. B. (2002). The Evolution of Global Positioning System (GPS)

   Technology. *Journal of Science Education and Technology*, 59–80.

Lawson, S. (2012, April 6). *Ten Ways Your Smartphone Knows Where You Are*.

   Retrieved from PCWorld:

   http://www.pcworld.com/article/253354/ten_ways_your_smartphone_knows_whe

   re_you_are.html

Liberty University. (2017). *Campus Construction*. Retrieved from Liberty University:

   http://www.liberty.edu/aboutliberty/?PID=27192

Ozdenici, B., Coskun, V., & Ok, K. (2015). NFC Internal: An Indoor Navigation System.

   PubMed Central, 7571-7595.

Park, M.-H., Hong, J.-H., & Cho, S.-B. (2007). Location-Based Recommendation System

   Using Bayesian User's Preference Model in Mobile Devices. In *Lecture Notes in*

   Computer Science (pp. 1130-1139). New York City: Springer Link.

Roth, R. E. (2013). Interactive maps: What we know and what we need to know. *Journal*

   of Spatial Information Science, 59-115.

Sataloff, G. L., Kaufman, C. C., & Levine, N. S. (2009). College of Charleston Campus

   Map. *Journal of Maps*, 9-18.

Smith, A. (2015, April 1). *U.S. Smartphone Use in 2015*. Retrieved from Pew Research

   Center: http://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015/

Ullman, L. (2011). *PHP for the Web.* Berkeley: Peachpit Press.

w3schools. (2016). *HTML <map> Tag*. Retrieved from w3schools:

      http://www.w3schools.com/TAGs/tag_map.asp

w3schools. (2016). *PHP 5 Tutorial*. Retrieved from w3schools:

      http://www.w3schools.com/php/default.asp

w3schools. (2016). *PHP MySQL Database*. Retrieved from w3schools:

      http://www.w3schools.com/php/php_mysql_intro.asp

w3schools. (2016). *w3schools*. Retrieved from w3schools: http://www.w3schools.com/

Wangsiripitak, S. (2014). In-Building Navigation System Using a Camera . *6th*

      International Conference on Knowledge and Smart Technology (KST) (pp. 35-

      40). Chonburi: IEEE.

Wilson, D. C., Lipford, H. R., Carroll, E., Karr, P., & Najjar, N. (2008). Charting New

      Ground: Modeling User Behavior in Interactive Geovisualization. *Proceedings of*

      the 16th ACM SIGSPATIAL international conference on Advances in geographic

      information systems (pp. 3757-3762). New York: ACM.

Wu, M.-Y., Tsai, S.-R., Wang, J.-C., & Chuang, Y.-C. (2010). A Pac-Man Game on

      Campus Using GPS Location Information and Shortest Path Algorithm. *The Third*

      IEEE Internation Conference on Digital Game and Intelligent Toy Enhanced

      Learning (pp. 202-206). Kaohsiung: IEEE.

Zhi-An, Y., & Liang-Qun, Y. (2012). The Design and Implementation of 3D Electronic

      Map of Campus Based on WEBGIS. *Information Science and Digital Content*

      Technology (ICIDT) (pp. 577-580). Jeju Island: IEEE.