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Campus Interactive Map Application

Alexander Duke, Ohio Northern University
Ethan Krause, Ohio Northern University
Mia Prasinos, Ohio Northern University
Lewis Schafer, Ohio Northern University

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Alexander Duke, Ethan Krause, Mia Prasinos, Lewis Schafer
Department of Electrical & Computer Engineering & Computer Science
Ohio Northern University
Ada, OH 45810, USA
Email: a-duke@onu.edu, e-krause@onu.edu, m-prasinos@onu.edu, l-schafer.2@onu.edu

Background

Every year, students, especially first-year students, have difficulty navigating Ohio Northern University's campus and struggle to find the buildings where their classes are held. While there are solutions that currently exist, such as campus signage, Google/Apple Maps, the Ohio Northern University Mobile App/University Website, and new student orientation tour events, no approach has adequately resolved the issue; causing the problem to reoccur every year for new students. The primary issue with the competing solutions is that they either do not have mobile-friendly functionality, require the student to have a good memory/understanding of campus, or do not contain university-specific information, such as landmarks, or classroom/office locations. With the issue and pain points isolated, the team can create an application that marries the strengths of each idea, while avoiding the identified pain points.

In the proposed application, there will need to be a high focus on privacy and data security, as certain aspects or features of the project involve knowing people's location and where they are going. In addition to location security, the application will need to comply with the Family Educational Rights Privacy Act (FERPA), which focuses on keeping student information confidential. With that, the application has to be developed securely and comprehensively to encapsulate the entirety of the campus. To begin scoping features for the application, the team distributed a student survey to gather metrics on how students currently navigate campus. The survey, found in Appendix B, included questions that determined their class year, knowledge of the location of certain buildings, understanding of the acronyms for buildings that may appear in their schedule, and how often the students leveraged the existing Ohio Northern University Mobile App. This helped the team understand the potential knowledge gap and how widely used the University Mobile App was by students. Once the results were analyzed by the team, they were then communicated to the client who provided input on the proposed primary features, as well as potential functionality the application may provide. This conversation also led to the client providing a Raspberry Pi 4 device to the team to aid in the development process.

This project will utilize knowledge learned from various courses in the curriculum, such as User Interface Design, Mobile App Development, Web Development, and Networks and Data Communications classes. The application will need to have a graphical user interface that is easy to use, accessible, and fits with the University branding guidelines. The same design considerations will need to be applied to the development knowledge and experience gained during Mobile App and Web Development since they will be critical to the user experience. Finally, the project will leverage knowledge gained during Networks and Data Communications

since the team will need to spin up web servers to host the project and test environments, as well as leverage different communication protocols throughout the process.

The primary stakeholders for this project will be the Office of Information Technology (IT), current students, and prospective students. IT will be the department responsible for any potential maintenance after this project concludes. With that said, IT will need a solution that is efficient, inexpensive, and easily maintained. Furthermore, current students, specifically first-year students, will want something that quickly helps them navigate the campus; with accurate time estimates between two locations. Prospective students will likely leverage the application to learn more about the many features that the campus has to offer, as well as learn some core information about the university that may not be available otherwise.

Constraints and Evaluation Metrics

To achieve the primary objective of the project, which is creating a mobile-friendly application that informs the campus community of locations on campus, the application will need to adhere to various constraints, which were determined by the client and team. The first constraint identified was maintainability, which ensures that the application is scalable and easily operated. As the project will be transitioned to the client after completion, they should be able to easily perform maintenance, upgrades, and other projects on the application, as this will ensure that the client can support the project's long-term success. In addition to the application being maintainable, it is also critical that the application is adaptable. This is especially important for a college campus, as there can be many changes that occur in short periods; such as the change of building hours, addition of buildings, and a shift in faculty members, to name a few; which will ultimately allow for the client to display updated information to the users with little inconvenience. Furthermore, the application's adaptability will also enable it to be expanded to other locations, such as the entire community (to support off-campus businesses, like El Campo, Rite Aid, and Starbucks). Another key constraint that the product needs to ensure is the privacy of users. Due to the nature of college campus information, there are federal regulations that must be followed, as well as the ethical duty to keep user data secure. This includes information like the user's name, location, contact information, or other sensitive information. Finally, the application should also be accessible cross-platform and be free to the student body. As the target audience for this product is college students, it is critical that students with all kinds of devices (Apple, Android, Samsung, Google, etc.) can leverage the tool and can do so without paying the University any additional fees.

While the team needed to assess project constraints, it was also necessary to determine key evaluation metrics. The first evaluation metric determined was the speed and usability of the product, as users will need to operate it easily with little runtime delay. A faster and more efficient product will result in a better user experience, as well as increase the usability of the application. To increase usability, the application will not only need to be fast but also will need to be easy to operate; meaning the user interface is easily digestible. Jumping off of application speed, accessibility is another key metric. As college students may be navigating campus during all times of the day, the product should be accessible at any time; meaning there should be very

little downtime. Additionally, another critical evaluation metric is the price of operations. As the project's client is internal to the University, the cost of operation should be relatively inexpensive; with the ideal cost being as low as possible. Finally, the last evaluation metric considered is the application's sustainability; in other words, how easily the client can operate and modify the provided application. As previously outlined, the client should be able to understand how the application operates and determine the next steps via the team's documentation.

Considerations

In addition to the determined constraints and evaluation metrics, the team had to consider many factors throughout the decision process; some of which align closely with them. The first consideration was how economically friendly the application was. As previously outlined, the product should be free for all students and cost very little to operate on the client's end. Jumping off of the economic factor, it was also important that the application had very little environmental impact, as it will need to use as little energy as possible (which will positively impact the cost of operation). Furthermore, the product should also leave a lasting social/cultural impact on the campus community, which is done by positively benefitting the students on campus. On the flip side of campus impact, the team also needed to consider whether the application should be scalable to other communities (such as another university, or the nearby schools); it was determined that the global impact would be very little, but may potentially impact the community outside of the University. The team determined that the safety and wellness of the users should be a key consideration, as the user will be exposing sensitive data (including location data) to the application. With that said, the application must ensure that all data being transmitted or stored is done so in an industry-standard and secure manner. Two final considerations that were leveraged during the process were the manufacturability and sustainability of the application, as they go hand-in-hand with the economics and environmental impact of the product.

Potential Solutions

Throughout the development and design process, the team considered multiple approaches to address the proposed issue at hand. From that process, the team was able to identify three solution approaches that would meet the client's needs:

1. A web-based application that would be accessible from any device by navigating to a specific web page on the University's domain. The benefits of this solution allow for compatibility across all platforms that support a modern web client, including mobile platforms such as Android, and iOS. This approach would also provide a variety of frameworks to leverage, such as Vue, Angular, and React, among others. The only constraints to this solution are web servers and database storage. An example sketch can be found in Figure 1, on the next page.

2. A mobile application that would be accessible by downloading it from the device's app

store, and would cost over $100 to have listed on the App Store/Google Play. The benefits of this solution allow for more in-depth features since it can use more functions from the devices, but would likely be more difficult to maintain cross-platform compatibility, and application security, and ensure easy accessibility (due to students needing to download the app originally). In addition to the previously mentioned constraints, there would also be limitations imposed by the existing application frameworks. An example sketch can be found in Figure 2, below.

3. An alternative solution to address the client's need would be to have a more "physical" component for the solution, such as posting QR codes around campus. Each QR code would redirect to a location that contains information about a building, or potentially directions to surrounding areas. The benefit of this solution would be the simplicity of the design, as it would be very easy to use. Additionally, it would not require much server bandwidth or database storage. The downside to this approach is that it would not provide much additional functionality and requires the user to physically locate a code. An example sketch can be found in Figure 3, below.

Figures 1, 2, and 3: Web App., Mobile App., and QR Code Approaches

Evaluation of Potential Solutions

Once the solution approaches have been considered, it was important to fairly and accurately assess which approach will best resolve the client's needs. To do so, the team leveraged a House of Quality matrix to weigh the benefits each solution provides. From that process, the team determined that Option 1, a web-based application best suited the client's needs and provided the optimal solution to the problem at hand. The matrix demonstrated that the product ultimately would achieve the client's needs, as well as provide a solution to the problem identified within the university community. The diagrams of this process can be found in Figure 4 and Table 1 on the next page.

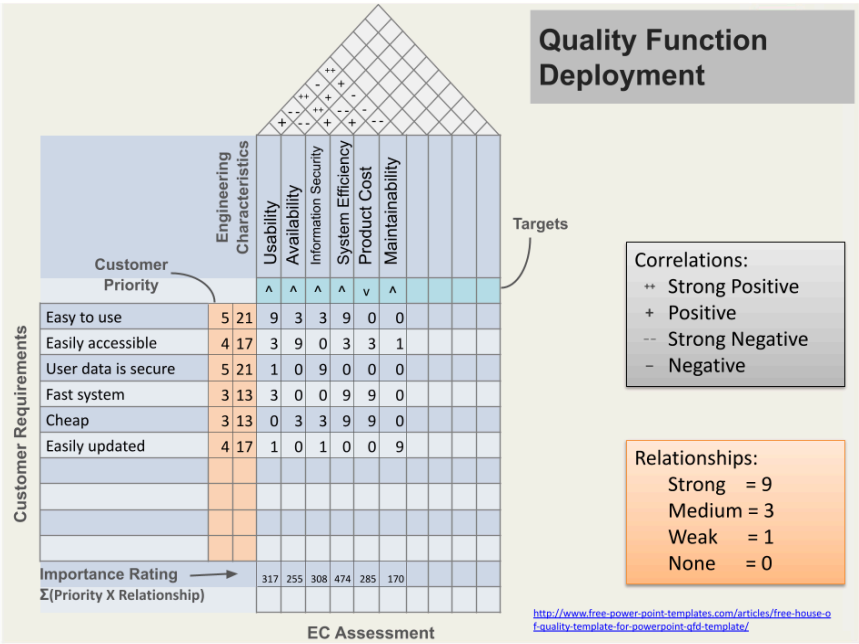

Figure 4: Quality Function Deployment Matrix

	Weight Factor	**Option 1 (website)**		**Option 2 (app)**		**Option 3 (physical)**	
Criteria		*Rating*	*Score*	*Rating*	*Score*	*Rating*	*Score*
Cost	20	0.1	2	0.2	4	0.5	10
Relevance	10	0.2	2	0.5	5	0.2	2
Sustainability	10	0.4	4	0.4	4	0.3	3
Impact	40	0.2	8	0.8	32	0.2	8
Efficiency	20	0.1	2	0.8	16	0.1	2
			18		61		25

Table 1: Solution Benefits Weight Table Selected Solution

As previously mentioned, the selected solution for this project is a web-based application approach. Through the design decisions and potential solution analysis, it was determined that this solution would cover nearly all the client specifications and criteria that have been set for the application. To make this solution feasible, the project utilizes a third-party software called "MapBox" to assist in the development process and to provide map and navigation APIs. MapBox uses Open Street Map, a website/database with an up-to-date view of sidewalks and other landmarks in different areas worldwide. Open Street Map is managed by community

contributors, which enables the map to receive frequent updates and ensure its accuracy, even on small campuses like Ohio Northern's[5]. The integration of Open Street Map allows MapBox to deliver a powerful solution by adding further functionality and features in addition to the strong navigational component. This enables the team to focus on campus-specific features/information as the application will not need to be built from scratch and will implement existing solutions; which address the identified scope concerns from the project review board.

Additionally, MapBox provides the ability to create an application with internal building and room navigation, which is something that was discussed in the feature development and decision process. MapBox also provides an SDK for web-based JavaScript development, which means the team can move forward leveraging MapBox's framework[2]. All of the functionality is provided at no extra cost and the software is accessible to anyone, which is why the team is determined to leverage MapBox as the backbone of the application to allow the focus of the project to be on the features students want to see.

Listening to feedback from the team's project review board presentation, the scope of the project was adjusted to ensure it was feasible to be completed throughout the capstone term. To help adjust the scope, the team determined that it will prioritize three buildings on campus during the project's development period: the IT Building, the JLK Engineering Building, and the McIntosh Center. The IT Building was selected as they are the client for this project and expressed interest in seeing their building included in it. The Engineering Building was selected as it is a familiar building to many students and was the primary audience of the student surveys. Additionally, it is also a very complex building, which allows it to showcase the potential of the application and modeling functionality. Finally, McIntosh was selected as it is a location that every student on campus visits, due to the variety of offices, food options, and events held within it. The team has already obtained the floor plans for all three buildings from Marc Staley, the Director of Facilities at Physical Plant. The floor plans are a great asset and enable us to quickly and efficiently implement building interiors into the application, further allowing the team to create a more realistic scope for this project and allowing for more focus to be placed on the features desired by both students and the client.

In discussions with the client, they also further specified a desire for localization and tracking capabilities for the application, which differs from the insight that had been provided by the pair review board. While originally the team planned to develop the mapping algorithm by scratch, MapBox's core functionality resolves the mapping problem and allows the localization requirement to be feasibly implemented into the final project. Furthermore, the client also expressed a desire for a "landmark" information feature to be focused on, as that is a function that will be able to be expanded and advertised. This can be designed in various ways, but the preferred method is a pop-up notification when a landmark is passed during navigation. Despite the addition of further requirements, the project is still within a feasible scope and they will help differentiate this application solution from existing competitors and benefit the target audience.

Manufacturing

To successfully develop and implement the application, the team will leverage a variety of frameworks and use agile methodology, which enables the client to provide frequent feedback and give flexibility within the project. On the hardware side of the project, the team will leverage three environments throughout the process. The first environment, where the developers will spend most of their time, is called 'development'; which is simply a locally hosted version of the product. Changes in this environment will not impact other development builds, making it a great opportunity for team members to experiment with features and functionality. Following the development environment, the team will also use a 'test' environment, which is an environment hosted on a server, hosted on the client-provided Raspberry Pi 4. This allows the team to upload less experimental functionality to a server environment and ensure that it functions properly in a network and not only locally hosted. Finally, the team's 'production' environment will be the University network and servers potentially provided by IT when the product is completed. Team members will rarely upload to this environment, as extensive quality assurance will be required before uploading. All-in-all, utilizing three environments will ensure the team is not only following the industry standard but also ensuring the security and quality of the project at hand while not impeding other team member's progress.

On the software and framework side of the project, the team has identified various third-party software that will significantly aid in the development of the project. The first and most prominent of the frameworks is MapBox, which has been described previously. MapBox will enable the team to cut the time to map campus significantly, as it provides functionality to map the interior of buildings and has already mapped the entirety of the outdoor campus. In addition to MapBox, the team is leveraging Angular within its development efforts. Angular is an open-source, TypeScript-based web framework that excels at developing single-page applications[3]. Angular is developed by a team at Google and is open-source, which allows the team to ensure the framework is trusted and secure. For the backend of the project, the team is using Spring Boot for the microservices and connection with the MongoDB database. Spring allows the team to focus development efforts on features rather than focusing on boilerplate code, as it helps accelerate the process when creating microservices. In addition to software the team will leverage, the team also uses GitHub as a form of version control. GitHub enables the team to efficiently manage branching and have multiple team members work in parallel throughout the project. Together, the software will allow the team to work more efficiently and prioritize functionality that both the client and target audience desire.

Conclusion

The team aims to design and develop a virtual campus navigation application for Ohio Northern University that will help students and visitors find their way around campus easily and conveniently. The application will have a user-friendly interface that allows users to search and locate buildings, rooms, amenities, and services on campus. Additionally, it will also provide step-by-step directions to their desired destination, ensuring that they stay on the correct paths and arrive at a location as quickly as possible. Jumping off the navigation functionality, the application will also provide information about locations on campus, such as historical information, hours of operation, important contacts, and interesting facts- essentially enabling the application to be a virtual tour guide.

The market potential for a digitized campus map is high, as there is a clear demand for a better campus navigation system among the Ohio Northern community. Current solutions are not as effective as navigation tools, nor provide user-friendly functionality. The proposed solution not only provides a comprehensive campus navigation experience that enhances the satisfaction of its users, but it also provides additional functionality that does not currently exist between the current implementations. As previously noted within the constraints and evaluation metrics, there will need to be a key focus on the application's flexibility, adaptability, and scalability. This is because the proposed solution should be expandable to other communities, such as the rest of the community or potentially other university campuses if the client desires to share the application.

The primary customer base for this application will consist of both prospective and current students, faculty members, staff, alumni, and visitors of the University. The application will be available for free on all web-capable devices, and will also be accessible through a standard web browser on any device (such as laptops, tablets, and computers).

With any campus application, user privacy and security are critical concepts that need to be considered. To ensure compliance with FERPA regulations, the application will not store or transmit any sensitive information about its users. Furthermore, due to client requirements, there will also be an emphasis on the scalability and maintainability of the application since it will potentially receive frequent updates and maintenance periods. The running costs for the application will depend solely on the operational and maintenance costs; such as web-hosting and app management costs required for running the application on servers or cloud platforms, as well as the cost of development time for adding additional features and information updates. Since it has been identified that the map will be offered free of cost for the end-user, it is implied these costs will be covered by the University, should they choose to maintain it as an official campus application. Appendix A, Project Management, discusses the logistics of some portions of the project; such as the time timeline and budget requests.

Bibliography

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2. "Mapbox", Mapbox, https://www.mapbox.com.
3. "Angular", Angular, https://www.angular.io.
4. "Mappedin", Mappedin, https://www.mappedin.com.
5. "Open Street Map", OpenStreetMap, https://www.openstreetmap.org.
6. "Spring Boot", Spring, https://spring.io/projects/spring-boot.

Appendix A: Project Management

The project leveraged a Gantt chart to generate an estimated timeline for the project. The team

also leverages agile methodology principles to ensure client satisfaction and adherence to industry standards.

Finally, the team has determined that it will request a budget of $1,000 from IT to cover the costs associated with the development process; which has been agreed upon by the client. Additionally, the client has agreed to provide a Raspberry Pi 4 to assist with the need for a test environment in the early development phases. An additional $300 will also be needed from the College of Engineering for 2 student's registration to the 2024 ASEE North Central Section Conference to present our capstone externally, along with lodging for the students in hotel rooms at $288, bringing the total to $1,588.00 covering all expenses.

Appendix B: Student Survey and Results

To gather feedback from the target audience, the team leveraged an IRB-approved survey to assess their previous use of the University Mobile App, knowledge of the campus, and desired features on a campus map mobile application. The survey asked the following questions:

1. What class year are you? *(multiple choice)*
    a. Freshman/P1
    b. Sophomore/P2
    c. Junior/P3
    d. Senior/P4 (or older)
2. How many times have you ever used an app to navigate campus? *(multiple choice)*
    a. 0
    b. 1
    c. 2
    d. 3+
3. Do you know where the following locations are: *(yes/no checkboxes)*
    a. McIntosh
    b. Information Technology Building
    c. PAC
    d. Stambaugh
    e. Polar Careers
    f. Registrar's Office
4. What features would you find most valuable for a campus map application? *(open-ended)*

At the time of review, the survey had nearly 50 results, which provided useful insights for the team to base feature decisions on. The results are shown in the following figures:

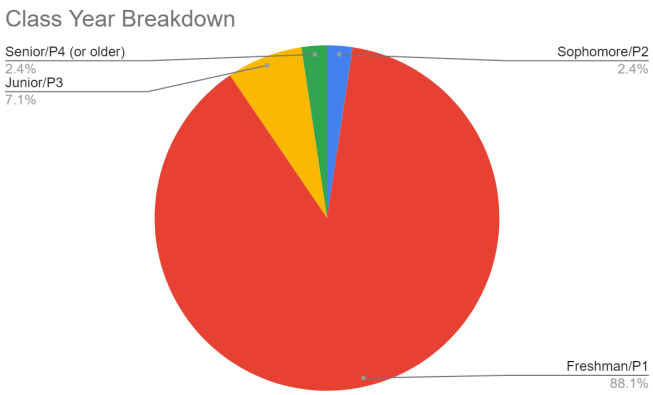

Figure 5: Class Year Breakdown Results

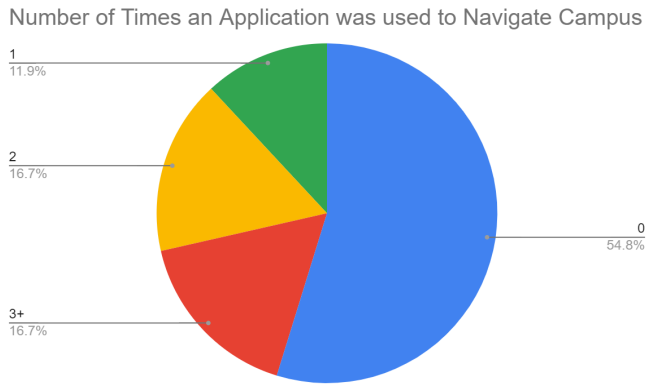

Figure 6: Campus Navigation Method Results

Figure 7: Desired Features Word Cloud

Appendix C: Parts List

1. Hardware

    a. Raspberry Pi 4
2. Software
    a. MapBox
    b. OpenStreetMap
    c. Angular
    d. Spring Boot
    e. GitHub