Letter of Submittal

Dear Dr. Nuxoll,

This is the final semester report for the capstone team "AR LEED Stories and BACnet Data Aggregator". Our project was to pull data from the Shiley Marcos Center of Innovation & Design and display it onto a web application. This report details the purpose and background of the project, as well as, go in depth into our contributions and work on the project.

Sincerely,

The "AR LEED Stories and BACnet Data Aggregator" Team

Shiley Augmented Reality LEED Stories & BACnet Data Aggregator
Final Semester Report

Team Members

Cian Murray, Henry Lee, Keoni Han, Dylan Price

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Faculty Advisor Signature: X

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1. Acknowledgements

Our capstone team would like to acknowledge the many people who contributed to the success of this project. This includes our industry advisors, Heather DeGrella and Kelli Kimura for their valuable design insights, as well as our technical specialist, Shem Heiple, for his networking with the I.S. Department and sharing his technical knowledge. We would also like to thank our faculty advisor, Dr. Matthew Reuben, and our capstone instructor, Dr. Andrew Nuxoll, for the guidance they provided to the team throughout the project.

2. Executive Summary

This project was created by Dean Fabian of the Shiley School of Engineering, and it involves creating a dashboard for the Shiley Marcos Center of Design & Innovation. This building is filled with many sensors that contribute to the building's eco-friendly design. In order to visualize this to the public and residents on campus, this dashboard brings users into an augmented reality world to explore stories about the building's construction and current operations, while showing data relevant to the sensors by showing trends in the data.

Our web application uses augmented reality (AR) to immerse users into the narrative of Shiley Marcos and its LEED (Leadership in Energy and Environmental Design) Certification [2]. Through intuitive interactions, users can explore the rich backstory, gaining deeper insights into the significance of the LEED Certification in sustainable practices. The application's backbone is built on the Spring framework, which ensures efficient data processing throughout the pipeline. This framework enables smooth communication between the front-end and the back-end. Creating captivating visuals through augmented reality that enhances storytelling and deepens

user immersion and a web page that provides relevant information and learning opportunities about environmental sustainability. This project will be a gateway for further research into environmental sustainability for students and faculty at the University of Portland.

3. Introduction

The Shiley-Marcos Center for Innovation & Design is a new building on the University of Portland's campus that was announced in September of 2022 and finished construction in January 2024. The designers of this new building made great efforts to ensure that the building's design was environmentally sustainable. In addition to prioritizing sustainable design, the designers also outfitted the building with sensors to measure data that would reflect the sustainable nature of the building.

The problem this project seeks to solve is simple. Until now, there has been no easily accessible place for the public to view information about the building's sustainable design or see that sustainability reflected through data. Our team seeks to solve this problem by aggregating that data into a database and displaying it on a publicly accessible web application. In addition to displaying data, the application is also capable of telling stories related to the building's design. This provides an easy-to-access and visually stimulating way for the students and faculty to view information that previously was difficult to access.

Users of this application would be people interested in doing research related to the building's carbon footprint during construction and current operations. The data may also be beneficial for environmental science students to use for student projects as well as spreading awareness for sustainable energy. Knowing the sustainability of the building may also appeal to prospective students touring the UP campus. If they are passionate about the environment, knowing the efforts the University puts towards sustainability may impact their decision to attend.

4. Background

The Shiley-Marcos building has a multitude of sensors that measure information. These include thermometers in every room to measure heat, sensors to measure air quality, the amount of electricity consumed and produced by solar panels. All of this data is pooled into what is known as a “Building Automation System” or BAS. In addition to this, the building has something called a “LEED” certification. LEED stands for Leadership in Energy and Environmental Design, and is the world's most widely used eco-friendly rating system in building architecture. Due to prioritizing sustainable design, the Shiley-Marcos Center seeks to achieve a LEED Gold certification, which is the second highest LEED certification.

Project Goals

There are 2 primary goals of this project. The first one is to retrieve the data from the BAS and display it on a web application. This is done through a backend data pipeline that pulls data from a database and displays it onto the pages of the web application through various formats like graphs. The second is to tell the “stories” of how the building earned its certification, also known as the “LEED Stories”.

Past Contributions

This project was initiated by a previous capstone team last year. This team developed a Python-based API to simulate pulling data from a database. They also supplied a database with mock data and designed a configuration page that allowed the user to adjust the number of buildings and sensors in the database.

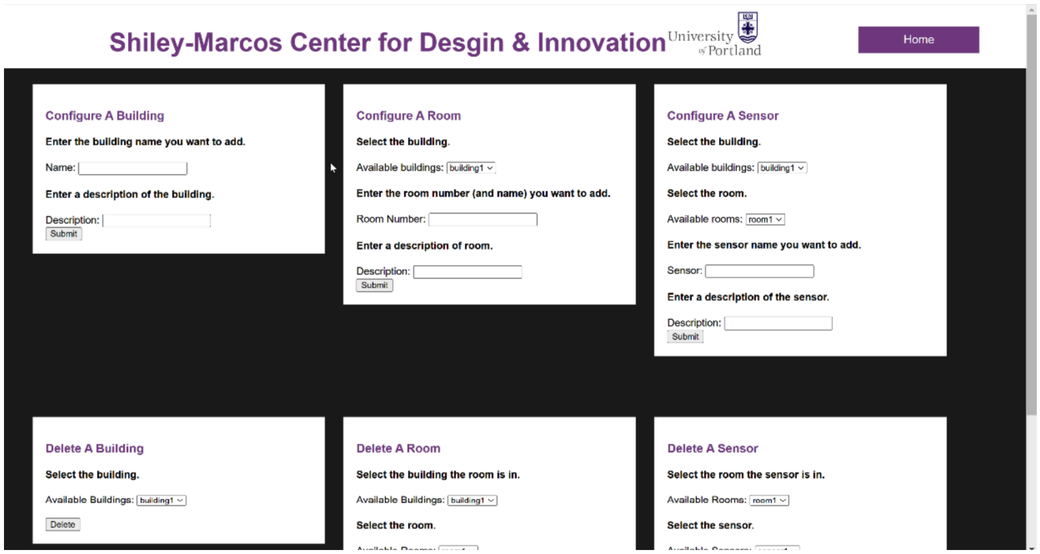

Figure 4: Previous capstone configuration page

This configuration page, while not used in our project, heavily influenced our design decisions when we developed our web application. Features like the use of official UP colors and logos to emulate the look of an official up product were retained in all of our designs this year. The application design was also influenced by the database structure created by the last group.

4.1 Relevant Standards

A standard relevant to this project is the Web Content Accessibility Guidelines (WCAG). These guidelines are a set of design principles that make web content more accessible to people with disabilities. These standards are important to us because we want our application to be accessible to as many people as possible, so we gave these guidelines much thought during the design process. WCAG has a number of recommendations designed to ensure pages can be easily navigated. One such principle is that the purpose of each link or button that takes the user to a new page should be able to be determined from the name of the link alone and that every web page of an application be accessible from any other web page of that application.

Recommendation 2.5.1 [1] recommends that whenever possible, webpages be designed in such a way where a user unable to use a keyboard be able to access all features and content of an application through using only a mouse.

We have strived to include as many of these accessibility features as possible into our application. All pages can be reached by clearly labeled buttons which are large enough as to be easily clicked. At no point is the user required to use a keyboard to navigate. The web application also avoids the use of flashing lights or harshly contrasting colors in order to accommodate people with epilepsy.

5. Design Criteria & Considerations

While designing this project we took 4 main characteristics into consideration. The first thing we made sure to be considered was an easy-to-use mobile user interface. This refers to designing an interface that is intuitive and simple for users to interact with on mobile devices. This includes using familiar UI patterns and gestures that other popular web applications may use.

We wanted to emphasize that these building sensors were very important in making sure that this building is efficient. This meant showing trends in data and presenting it in a way that allows users to easily identify patterns, correlations, and trends over time. Some specific things that we considered were using common visualizations such as line graphs, bar charts, and pie charts to represent trends in the data. We also provided interactive elements that allowed users to change the time periods or data subsets.

The most important component was augmented reality (AR) functionality because it helped enhance the user experience by overlaying digital content onto the real world. Showing visuals through the camera helps users visualize certain aspects of the building and can help them understand the significance of these systems. We also wanted it to be accessible on mobile devices as this would be where most people would be accessing the web application from.
The last important thing we considered was the color scheme of the project. This plays a crucial role in the overall look and feel of the interface and can influence user perception and engagement. We chose colors that reflected the University of Portland, and industry standards. For example, the colors for the temperatures on the floor plan page are colors that many companies use to represent these temperatures. We also tested the color scheme across multiple devices to make sure it was aesthetic and that text was readable. Along with this we also wanted the webpage to change size dynamically based on the device they were accessing the web application from.

6. Design Comparisons

Our solution offers strengths and weaknesses in each component that we considered when designing this project.
The previous team used the Flask API using Python which after much deliberation decided to go for a Java based framework called Spring. This is due to Spring being an industry standard [4]. This framework is much faster and secure than Flask. We also decided to use a Java based framework because at the University of Portland, all incoming Computer Science majors will

have to learn Java. This leads to students not having to spend more time learning a new language and already having a strong familiarity with the code base.

An alternative to the current user interface could be a more complicated one filled with more features and customization that some tech-savvy users would prefer. We considered adding videos that would play in the background, customizable modular graphs that users could move around and adjust using advanced data filters. Our team decided not to go with this type of user interface as this would be complicated for the average user. Also most use cases that we looked over proved that most students would not use advanced data filters.

For showing trends in data through our graphs, a strength of this is showing the emphasis on showcasing trends in data through various visualizations like line graphs, bar charts, and pie charts which enable users to easily identify patterns and correlations, enhancing data comprehension. The weakness of this is depending solely on visualizations it may overlook users who prefer textual or auditory data presentation methods. Additionally, too many visualizations or overly complex ones could overwhelm users.

7. Final Design Overview

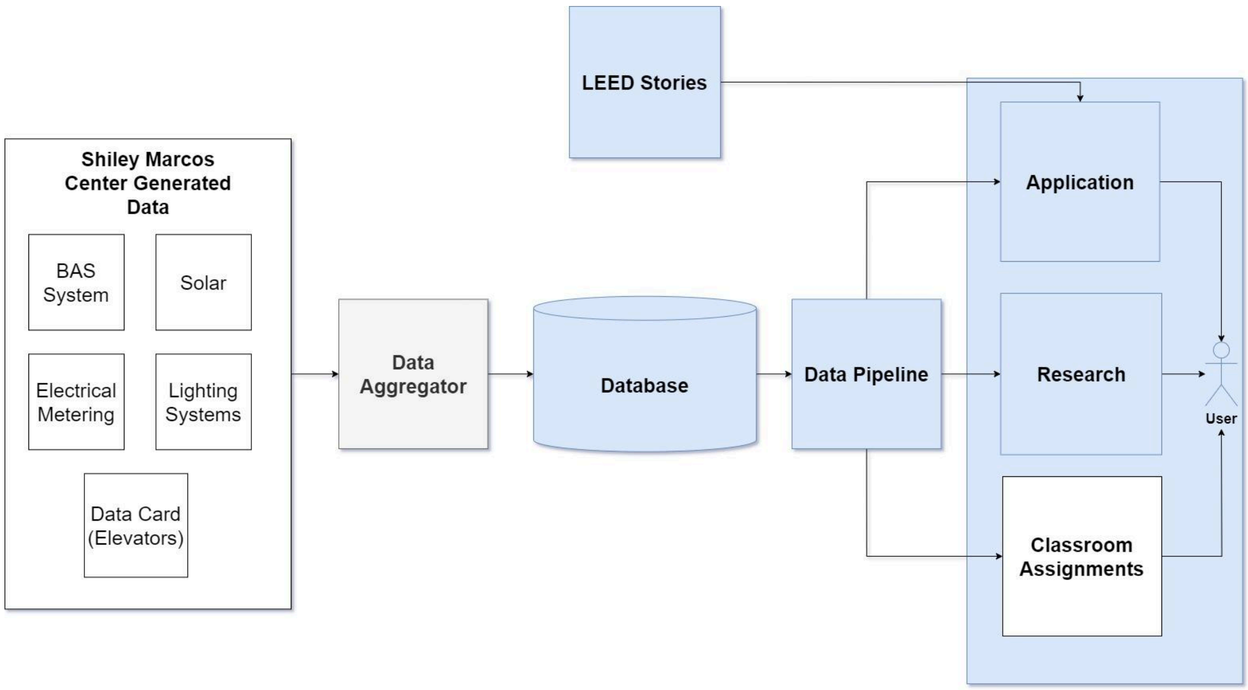

Figure 7.1: Block Diagram of the Project

This project involves pulling live data from various meters within the Shiley-Marcos Center into a database, and then displaying them onto a web application as shown in figure 7.1. For our time on the project, we focused on the development of the web application and the LEED Stories. This web application includes a Java-based Spring service pipeline which acts as a connecting medium between the web application and the database, as well as a webpage that displays the data. Another part of the project is LEED stories, which uses augmented reality and 3D models to show the different factors that make the Shiley-Marcos Center environmentally friendly. The web application itself uses React, JavaScript, HTML, and the implementation of various third-party libraries to display the data stored in the database onto the webpage.

This web application includes multiple pages that allow for different types of data and information to be displayed. The web application includes a wide variety of pages. The first page is a home page that gives a summary of the building. The second page shows the LEED Stories which presents the information as cards. The third page is on thermal comfort which details the temperature and humidity of the building. The fourth page details the air quality of the building. The final page details information on solar and electricity.

To run the application, the user runs both the backend data pipeline, as well as the web application. Running the web application will display the webpage and running the pipeline allows the data from the database to be displayed on the graphs and floorplans.

8. Analysis of the Final Design

8.1 LEED Stories Models

Our application makes use of augmented reality in order to present the various LEED stories about the Shiley Marcos Center for Design & Innovation to users. Currently this augmented reality application functions by displaying digital objects into a space when viewed through a mobile device's camera.

These digital objects can be modeled in the free and open source 3D computer graphics software, Blender. This software has many features that allow for digital objects to be modeled and textured from scratch in a short amount of time and is very easy for beginners to learn. Blender [3] has features that allow the user to easily model text, so in addition to an object that serves as a visual representation of the information, we can also include a text description to accompany it. It also allows for the user to export digital objects to a .glb file type, (a file format for transmitting 3D data) which is a file type compatible with the augmented reality library our web application uses. Once the digital objects have been created and exported to a .glb file, they can be added to an open source augmented reality environment called model-viewer, where the user can view them on their mobile device. The user then has the ability to scale the models by pinching or expanding them.

8.2 Backend Data Pipeline

Spring Boot

This project relies heavily on pulling data from a database to a front-end application. The backend data pipeline uses the Spring Boot framework which is a Java-based microservice architecture. A microservice architecture splits an application into a series of independently deployable services which allows for better team productivity, accelerated scalability, and for multiple database usage. It also allows for team members to make changes without potentially affecting or compromising the entire application. Spring is a Java based framework, platform, and library that is frequently used to build applications in companies. It is frequently used due to it having flexible and comprehensive extensions, radically streamlining tasks, fast performance time, and high security. Spring Boot is specifically very good support for building RESTful web applications. Spring Boot is also able to develop stand-alone and production-grade spring applications that are easily runnable. It can also increase productivity and decrease development time. Some of the features of Spring Boot are that it provides powerful batch processing, manages REST endpoints and is a way to call data from the database to the front-end. It is also auto configured with no manual configurations needed and can automatically configure an application based on the dependencies. For example, if MySQL database is on a class path, but the database connection has not been configured, then Spring Boot will auto-configure an in-memory database.

Building RESTful Web Services and Annotations

To build the RESTful Web Services, the Spring Boot Starter Web dependency has to be added into the build configuration file. There are also annotations that are useful in building the application. The @RestController annotation is used to define the RESTful web services, and services JSON, XML, and custom responses. The @RequestMapping annotation is used to define the Request URI to access the REST endpoints. The @RequestBody annotation is used to define the request body content type. The @PathVariable annotation is used to define the custom or dynamic request URI. The @RequestParameter annotation is used to read the request parameters from the Request URL.

Pipeline Process

The backend data pipeline makes connections to our pages in the front-end web page including the thermal comfort page, the solar page, and the air quality page. These connections are shown by creating dummy data in the backend data pipeline, then drawing and displaying that data onto the respective pages through graphs or other visual means until real data from the building is substituted in.

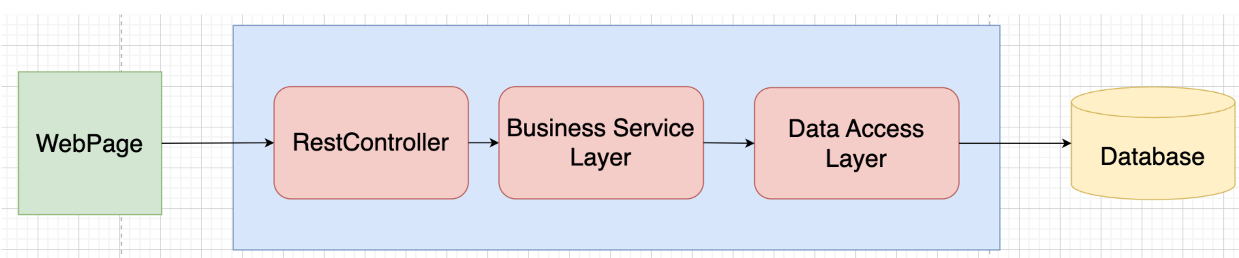

Figure 8.2: Block Diagram of Backend Data Pipeline

As shown above in figure 8.2, when the webpage calls the backend for data, the traffic first reaches the services by hitting the endpoint which is defined in the RestController. A Rest controller is responsible for handling a HTTP (or link) request and returning the HTTP response to the webpage. The Rest controller extracts the input parameters from the service call payload. Then it will invoke the business method defined in the service layer to perform business logic which is getting data from the data repository. The business logic calls the data object which is defined in the data access layer which then grabs the data from the database. In this way, if the data within the database needs to be changed, only the data access layer needs to be changed to call the database to get the new data while all other layers can remain the same.

8.3 Front-End Application

The front-end application is a web page that will display information relating to its environmental sustainability about the Shiley Marcos Center for Design & Innovation. These pages include the home page, the thermal comfort page, and the electricity/solar page. The home page includes a slideshow of images from the Shiley Marcos Center and a description of the building. The second page shows the LEED Stories which presents the information as cards. Additionally, mobile devices have the option to see the model through a virtual environment space.

Thermal Comfort

The thermal comfort page is split into two sub-pages. One page shows two graphs, a line graph which details the temperature inside and outside the building throughout the week and a percentage graph that shows the outdoor humidity. The other page shows a floor plan of the building with the temperature of each room being shown, while also being color coded based on its temperature.

Air Quality

This page includes a percentage graph showing the air quality index with a description contextualizing the different air quality index values.

Electricity/Solar

The electricity/solar page contains two graphs, one showing how much energy the building consumes in a day. This can be changed to view weekly, monthly, and yearly data. Another graph shows the electrical usage of multiple systems in the building including the elevators, HVAC system, and lighting. All the data that is being displayed on the pages will be dummy data drawn from the backend data pipeline until data from the building is substituted in.

9. Conclusions

The overall objective of this project is to develop a dashboard for the Shiley-Marcos Center for Design & Innovation. The dashboard uses data from the building and showcases the university's efforts toward a cleaner and more sustainable future. Our goal was to create an appealing web application while fully implementing the data aggregation and augmented reality (AR) LEED story aspects of the project. However, due to unforeseen circumstances throughout the project, we were unable to gain access to data from the building's sensors. Despite this, we were able to develop a web application that uses a backend data pipeline to pull and display "dummy" data. We were also able to make significant progress in developing infrastructure needed to create the

LEED stories. This includes a pipeline for creating AR content by utilizing a 3D modeling software called Blender and a library for AR displays called Model Viewer. If a future team were to pick up this project, their main goals would be to implement the display of actual data from the Shiley-Marcos Center for Design & Innovation onto the front-end of the web application, use the existing AR infrastructure to create more LEED Stories, improve the overall design of the web application, and research how to retrieve data from solar panels and electrical meters.

Appendix A: Roles and Responsibilities

<u>Keoni Han</u>

- Team Lead (Sprint 1, 6)
- Facilitates all meetings and helps the team understand deadlines and common objectives. Lead designer of the web application homepage.
- Created the framework that displays the AR models on the LEED Stories page.
- Made contributions to the frontend design of the Air Quality and Humidity/Temperature (also known as thermal comfort) pages.

<u>Dylan Price</u>

- Team Lead (Sprints 4, 5)
- Responsible for taking notes during meetings with clients/advisors, providing the rest of the team a synopsis of what was discussed during each meeting.
- Lead designer of the Electricity/Solar portion of the web application
- Responsible for creating and connecting the corresponding data endpoints in the backend data pipeline.

<u>Henry Lee</u>

- Team Lead (Sprint 3)
- Coordinates meetings with other group members and clients/advisors, maintains connections, and notifies everyone involved with the project of any major updates.
- Built the framework of the backend data pipeline for the backend of the web application and created data endpoints in the pipeline for the backend of the Humidity/Temperature page.
- Contributed to the frontend design of the Humidity/Temperature page.

Cian Murray

- Team Lead (Sprints 2, 7)
- Considers the most effective and practical method(s) to achieve team objectives.
- Designs augmented reality (AR) models for the LEED Stories portion of the web application.
- Created the preliminary Humidity/Temperature page and made contributions towards its final design.

Appendix B: Budget

This project was developed using free software, and as a result did not require funding. However, aspects of the project that have yet to be implemented will require funding. For security reasons the University of Portland's information services department will not provide non-department members access to their databases. As a result, software to pull data from these databases will need to be developed by the information services department internally. Currently it is estimated that development of a proof of concept for such software will cost $2,000 to produce, with the full proof of concept costing $10,000. This requires funding approval from the Dean of the Shiley School of engineering, which as of April 2024 is still pending.

Works Cited

[1] W3C. World Wide Web Consortium. Available: https://www.w3.org/ (accessed Apr. 19, 2024).

[2] LEED Certification, https://support.usgbc.org/hc/en-us/p/leed-certification (accessed Apr. 19, 2024).

[3] B. Foundation, "Home of the blender project - free and open 3D creation software," blender.org, https://blender.org/ (accessed Apr. 19, 2024).

[4] Spring Framework. "Why Spring?" spring.io, Available: https://spring.io/why-spring. (accessed Apr. 19, 2024).