CS 426: Software Engineering

Project Assignment 2

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1 Abstract

The project proposal will encompass a museum guidance robot with the focus on accessibility for participants through remote services or guided interactivity in place of human guides. The main purpose of this project is to address the current concerns regarding COVID-19 with the limit to the amount of participants and employees in the space. ADA museum guidelines will also be addressed to accommodate visual and auditory needs. This project intends to develop a functioning general use guidance robot to assist in various museum information delivery with potential mobile or web user interfaces for museums in the Reno-Tahoe area with a focus on those in the University of Nevada, Reno.

2 Recent Project Changes - Sherman

There have been no major recent changes.

3 Updated Specification

Section 3.1 - Summary of Changes in Project Specification

There have been no major changes in the project specifications. Only one change has occurred, we will not be using Arduino for the robotic system, and we will instead use an onboard computer such as a Raspberry Pi or a laptop. This change occurred on the recommendation of Dr. Feil-Seifer. Beyond that, our requirements have stayed as anticipated.

Section 3.2 - Updated Technical Requirements Specification

Functional Requirements

FR01: [1] Robotic Docent shall first map the museum
FR02: [1] Robotic Docent shall provide an application that displays the map
FR03: [1] Robotic Docent shall provide users the option to select areas in the map to declare them exhibits
FR04: [1] Robotic Docent shall allow the user to directly input a script corresponding to the exhibit
FR05: [1] Robotic Docent shall allow the user to plan a tour route through the museum
FR06: [1] Robotic Docent shall allow the user to choose areas where the robot is positioned when it's not giving a tour
FR07: [1] Robotic Docent shall allow the user to edit scripts for the exhibits
FR08: [2] Robotic Docent shall allow the user to directly input actions that the robot can respond to
FR09: [2] Robotic Docent shall allow the user to directly input the response to an action
FR10: [2] Robotic Docent shall allow the user to schedule times when the tours occur
FR11: [2] Robotic Docent shall allow the client to ask questions when it is not giving a tour
FR12: [2] Robotic Docent shall give the client the option to ask it where an exhibit is located
FR13: [2] Robotic Docent shall guide the client to that exhibit
FR14: [2] Robotic Docent shall collect video and audio
FR15: [2] Robotic Docent shall send video and audio to the application
FR16: [2] Robotic Docent shall provide users with the ability to access video and audio
FR17: [3] Robotic Docent shall give the users the ability to see what the docent sees at any time

Nonfunctional Requirements

NFR01: [1] Robotic Docent will be implemented in ROS
NFR02: [1] Robotic Docent will have a graphical interface for museum personnel
NFR03: [1] Robotic Docent will not start another task before it finishes the current one
NFR04: [1] Robotic Docent application will be Windows compatible
NFR05: [1] Robotic Docent shall use a computer and Pioneer for the robot hardware
NFR06: [1] Robotic Docent shall use wheels to move around
NFR07: [2] Robotic Docent shall use a speech recognition API
NFR08: [2] Robotic Docent shall accept input with verbal commands

NFR09: [2] Robotic Docent shall send the application video and audio after every tour NFR10: [3] Robotic Docent application will be MacOS compatible

Section 3.3 - Updated Use Case Modeling

Use Case Diagram

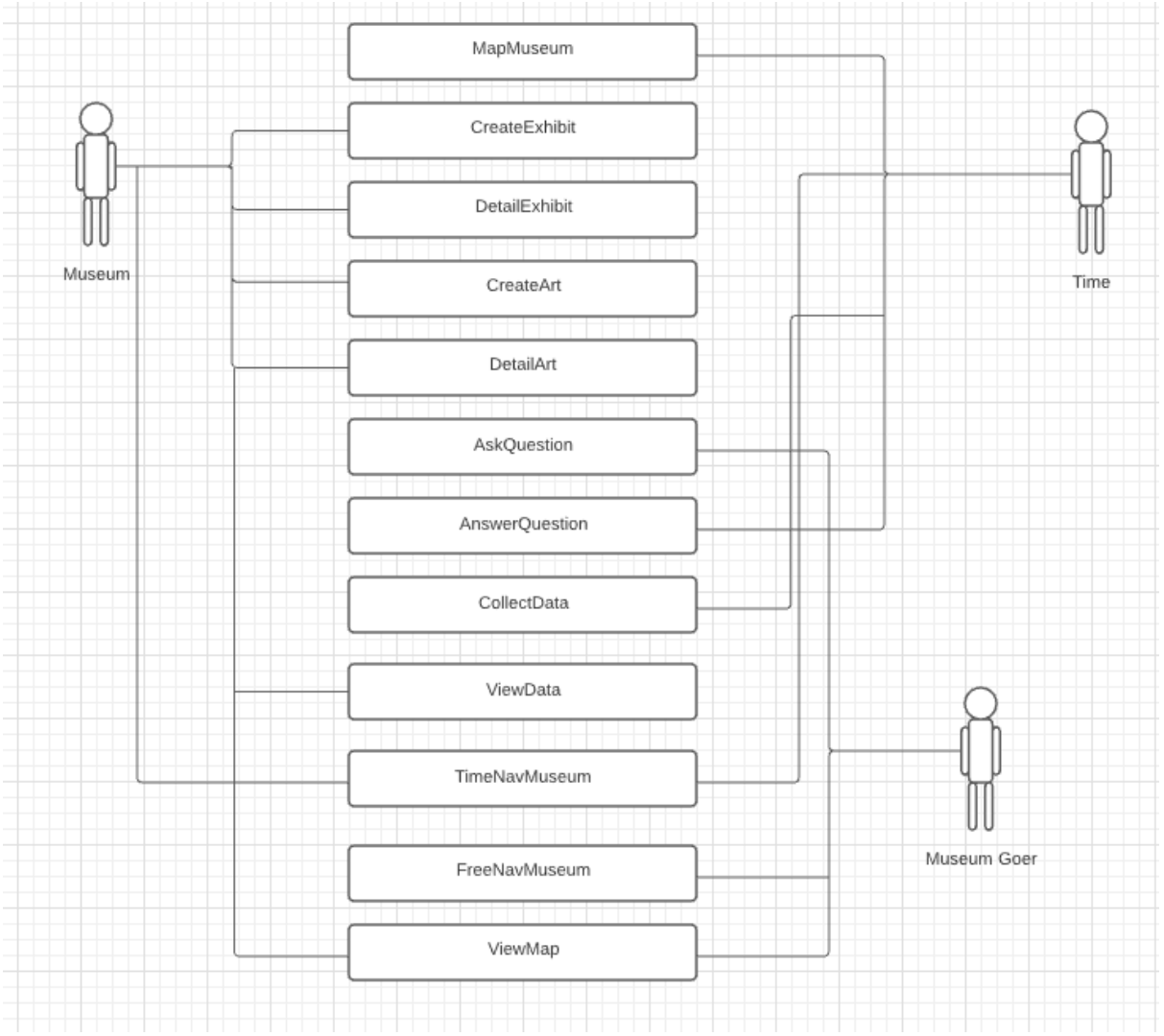


Fig. 1: The Use Case Diagram showing how the Museum, Museum Goers, and Time actors interact with use cases.

Detailed Use Cases

ID	Use Case	Description
UC01	MapMuseum	The Robotic Docent will have a startup procedure of mapping the museum and generating a 2D layout of the museum for the UI
UC02	CreateExhibit	The museum will be able to mark areas on the 2D generated map that act as the exhibit space so the Robot Docent can identify and navigate to it
UC03	DetailExhibit	After creating the exhibit space, the museum can provide additional information about the space that will be relayed through the robot or delete it altogether.
UC04	CreateArt	After an exhibit space is created, the museum can add individual art pieces so the robot can navigate to precise locations.
UC05	DetailArt	The museum can add further information to the created art spaces that the robot will relay or remove them.
UC06	AskQuestion	The museum goer can ask a question to the robot (additional information about an exhibit, details about a piece in the museum, etc.) through text or speech
UC07	AnswerQuestion	The robot will answer the museum goers question(s) both through its museum generated database and mapping services.
UC08	CollectData	With audio and visual sensors, the robot will record data on the museum such as traffic, demographics, and busy times.
UC09	ViewData	The museum will be able to view and transfer data the robot collects in order to analyze it.
UC10	TimeNavMuseum	The museum can schedule a tour that will occur at the time provided by the museum, and give pre-recorded information. The museum goers will be able to interact with the robot throughout the tour.
UC11	FreeNavMuseum	While the robot is in the museum and not doing any other function, a museum goer can get the robot to help them navigate through the museum and provide a “free form” tour.
UC12	ViewMap	After the map is generated, both the museum and museum goer can view the map.

Detailed Templates

Use Case: MapMusuem	
ID	UC01
Actor	Time
Preconditions	1. The robot is securely placed inside the museum 2. The museum is powered on and in a new environment
Flow of Events	1. The robot will navigate itself throughout the entire museum space 2. While navigating, it will map the museum surfaces and create a 2D map
Postconditions	1. A 2D map will be generated

Use Case: DetailExhibit	
ID	UC03
Actor	Museum
Preconditions	1. A map of the museum has been generated 2. An exhibit has been created on the map
Flow of Events	1. The museum can add information broadly about the exhibit in a details panel 2. The museum can select points in the exhibit area to add details to specific locations
Postconditions	1. The exhibit is labeled and has additional details

Use Case: TimeNavMuseum	
ID	UC10
Actor	Time/Museum Goer
Preconditions	1. A map of the museum is generated 2. An exhibit and art pieces with the exhibit are generated and labeled 3. A script of the tour is provided 4. A start and end time for the tour is provided 5. A route is provided
Flow of Events	1. The robot will wait at start location until time to begin tour 2. Once the time comes, the robot will go through the provided route and guide people through the museum/exhibit 3. The robot will also ask and answer questions throughout the tour 4. Once done, the robot will stay for a Q and A session and leave to its next location
Postconditions	1. Robot moved to a new location 2. Robot delivered information

Use Case: FreeNavMuseum	
ID	UC10
Actor	Museum Goer
Preconditions	1. A map of the museum is generated 2. An exhibit and art pieces with the exhibit are generated and labeled 3. The robot is not doing any other functions 4. A museum goer requests a tour
Flow of Events	1. After the museum goer requests a location to be taken to, the robot will create a route to that location 2. The robot will then guide the museum goer to said location while also answering other questions they have 3. Once arrived, the robot will ask for any further inquiries before leaving to another location
Postconditions	1. The robot has successfully guided the museum goer 2. The robot has moved from its initial location 3. The robot has provided the museum goer with the proper information

Requirement Traceability Matrix

	UC01	UC02	UC03	UC04	UC05	UC06	UC07	UC08	UC09	UC10	UC11	UC12
FR01	■											
FR02												■
FR03		■		■								
FR04			■		■							
FR05												
FR06												
FR07			■		■							
FR08												
FR09						■						
FR10										■		
FR11						■	■					
FR12						■						
FR13										■	■	
FR14								■				
FR15									■			
FR16									■			
FR17												

Fig. 2: The requirement traceability matrix displaying the mapping of functional requirements and use cases.

4 Updated Design - Kyle

Section 4.1 - Summary of Changes in Project Design

As development continued on the project, the overall design has been modified to reflect different concerns and add new functionality. Most changes can be found in the structure of the database. For example, the database now includes user data to ensure that users can properly log in and access the map editor platform. The map blob in the floor table has been pulled out and replaced with a map_id where the id corresponds to a blob in a different database style. It didn't make sense to store a whole blob into the PSQL database, which often made the database clunky. Instead we will introduce a new system to store photos. After toying with storing images in the database, we have decided to move away as it makes the database ugly; the recommended fix was to store photos as files somewhere else and map to it.

The mobile website system and its functionality for museum goers were also designed and improved. Prior to this, the website was not fully fleshed out and was out of the picture. After some research and development, we think it is feasible to go ahead and build a platform for museum visitors to interact with the robot.

Other than these changes, no other significant changes were made on the system that would impact how the system performs as a whole.

Section 4.2 - Updated High-level and Medium-level Design

System-level Design Diagram

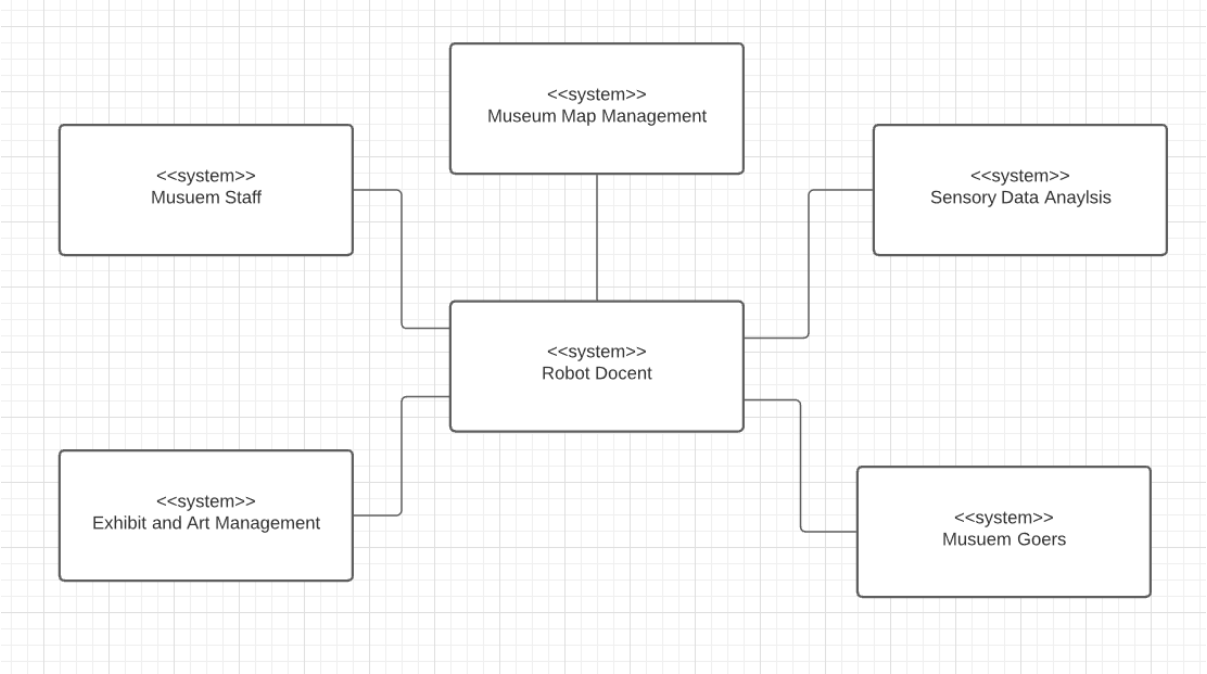


Fig. 3: The Context Model of the Museum Robot Docent.

Program Units

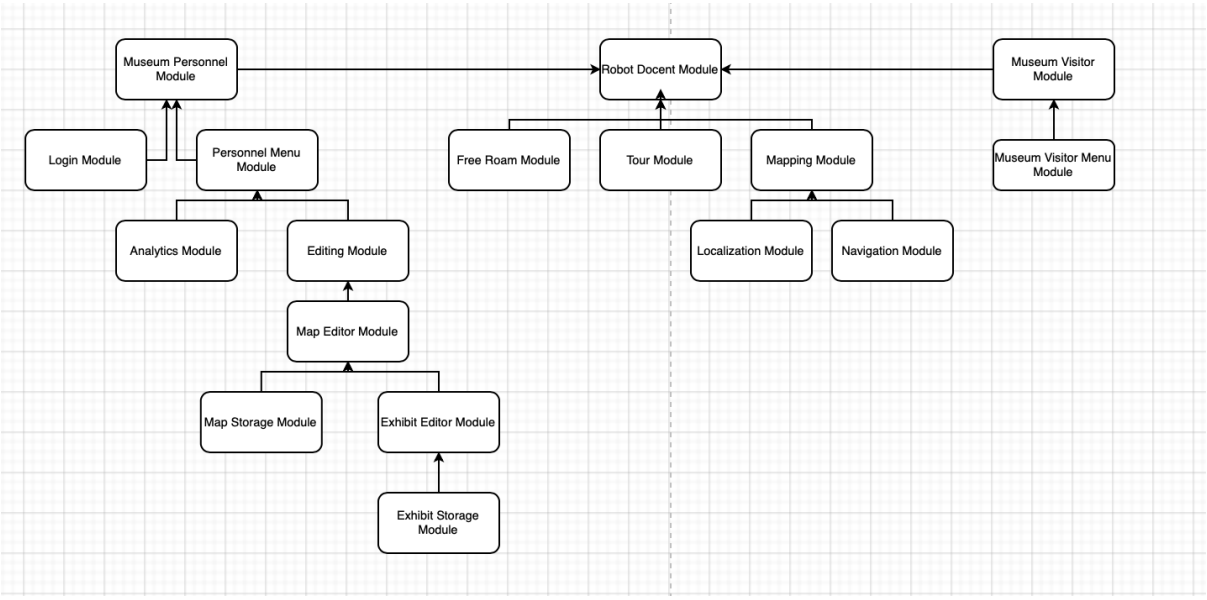


Fig. 4: The following is a diagram of the different program units and how they interact with each other. The units have been classified in terms of modules, with certain modules being subcomponents of other modules. The following section details each module and the interaction between modules.

Museum Personnel Module:
The Museum Personnel module encapsulates the Login module and Personnel Menu module. The Museum Personnel module receives data from these modules, and sends it to the Robot Docent module, while also receiving data from the Robot Docent module. The data that the Museum Personnel module receives is information regarding the map and analytics from the robot, while the data that it sends is information regarding the exhibits and tours. This module is in charge of making sure that the appropriate submodules get the needed information, and it is also responsible for communication with the robot.

Login Module:
The Login module ensures that the appropriate personnel can log into the system and passes their credentials to the Museum Personnel module, so then the Museum Personnel module can track what is being done.

Personnel Menu Module:
The Personnel Menu module encapsulates the Analytics and Editing modules, and receives information from the Museum Personnel module in order to initialize the encapsulated modules. It receives credential information in order to track the changes made, it receives the map and exhibit information in order to pass the information to the Editing module, and it passes the analytics information to the Analytics module in order to display those results. The Personnel Menu module also receives information from the Editing module in order to pass it to the Museum Personnel module.

Analytics Module:
The Analytics module receives information from the Personnel Menu module that includes different statistics from the robot and displays these statistics.

Editing Module:
The Editing module receives information from the Personnel Menu module that includes the map and exhibit data. The Editing module then encapsulates the Map Editor module and passes the information down.

Map Editor Module:
The Map Editor module encapsulates the Map Storage and Exhibit Editor modules. It receives information from the Editing module and passes the map information to the Map Storage module, and the exhibit information to the Exhibit Editor module. The Map Editor module directly edits the information in the Map Storage module, and allows the user to change where exhibits are at.

Map Storage Module:
The Map Storage module stores the map that is directly worked on by the Map Editor module. It receives information from the Map Editor.

Exhibit Editor Module:
The Exhibit Editor module encapsulates the Exhibit Storage module and receives information from the Map Editor module. It allows the user to directly edit the content of exhibits and stores it in the Exhibit Storage module.

Exhibit Storage Module:
The Exhibit Storage module receives information from the Exhibit Editor module and stores it. The Exhibit Editor module directly edits the information in here.

Robot Docent Module:
The Robot Docent module encapsulates the Free Roam, Tour and Mapping modules. It receives information from both the Museum Visitor and Museum Personnel modules and sends information to the Museum Visitor, Museum Personnel, Free Roam and Tour modules. It sends the setting that it is in to the Museum Visitor module, whether it is the free roam setting or the tour setting, and then receives actions from the Museum Visitor module. The actions it receives from the Museum Visitor module can be either asking for more information about an exhibit or directions to a specific location. It sends the map and exhibit information to the Museum Personnel module and also receives the updated information from the Museum Personnel module. Depending on the mode it is in, it either sends the command information to the Free Roam or Tour module, where the command is then executed.

Free Roam Module:
The Free Roam module communicates with the Robot Docent module. This is where all of the free roam features of the robot are encapsulated. The Free Roam module receives commands and executes them. When the robot is in free roam mode, any museum visitor may approach it to ask it for directions to exhibits and for information on the exhibits.

Tour Module:
The Tour module communicates with the Robot Docent module. This is where all of the tour features of the robot are encapsulated. The Tour module receives commands from the Robot Docent module and executes them. When the robot is in tour mode, it will only allow the museum visitors to ask for more information on certain exhibits and it follows a preset path.

Mapping Module:
The Mapping module communicates with the Robot Docent module and encapsulates the Navigation and Localization modules. The Mapping module is in charge of mapping the museum using the Navigation and Localization modules, and sending the map to the Robot Docent module. It also sends the navigation commands from the Tour and Free Roam modules to the Navigation module in order to move the robot where it needs to go.

Navigation Module:
The Navigation module communicates with the Mapping module in order to navigate the robot where it needs to go. The Navigation module is in charge of navigating the robot without bumping into any obstacles.

Localization Module:
The Localization module communicates with the Mapping module in order for the robot to know where it is located in the museum space. It sends this information to the Mapping module in order to aid in navigation.

Museum Visitor Module:
The Museum Visitor module encapsulates the Museum Visitor Menu module and communicates with the Robot Docent module in order to send commands. It receives the user commands from the Museum Visitor Menu module and also updates the Museum Visitor Menu module depending on the setting that it receives from the Robot Docent module.

Museum Visitor Menu Module:
The Museum Visitor Menu module allows for the visitor to interact with the robot, and it changes depending on whether the robot is in free roam mode or tour mode. It sends the commands to the Museum Visitor module.

Main Data Structures and Database Design

The robotic component will mainly require a computation graph to create a communication network to efficiently process data together. This graph is made out of nodes, masters, parameter servers, messages, topics, services, and bags. Nodes are the basic building blocks to this network and allow the system to stay modular; for example, a node may represent control over the wheel motors. The master and parameter servers act as dictionaries for the nodes to find each other. Messages are the base data structure that is used to pass information from one node to another. These messages can be thought of as large structures containing primitive data types along with nested data structures such as arrays. Bags can be used to store these messages. Topics and services allow for flexible communication between different nodes, so that messages can be communicated to the right nodes.

The frontend editing platform will utilize React components. These components may contain several data structures; however in particular, arrays will be the most frequently used structure to effectively show changing data. Arrays are easy to iterate through and thus are optimal for showing lists of objects such as pieces in an exhibit.

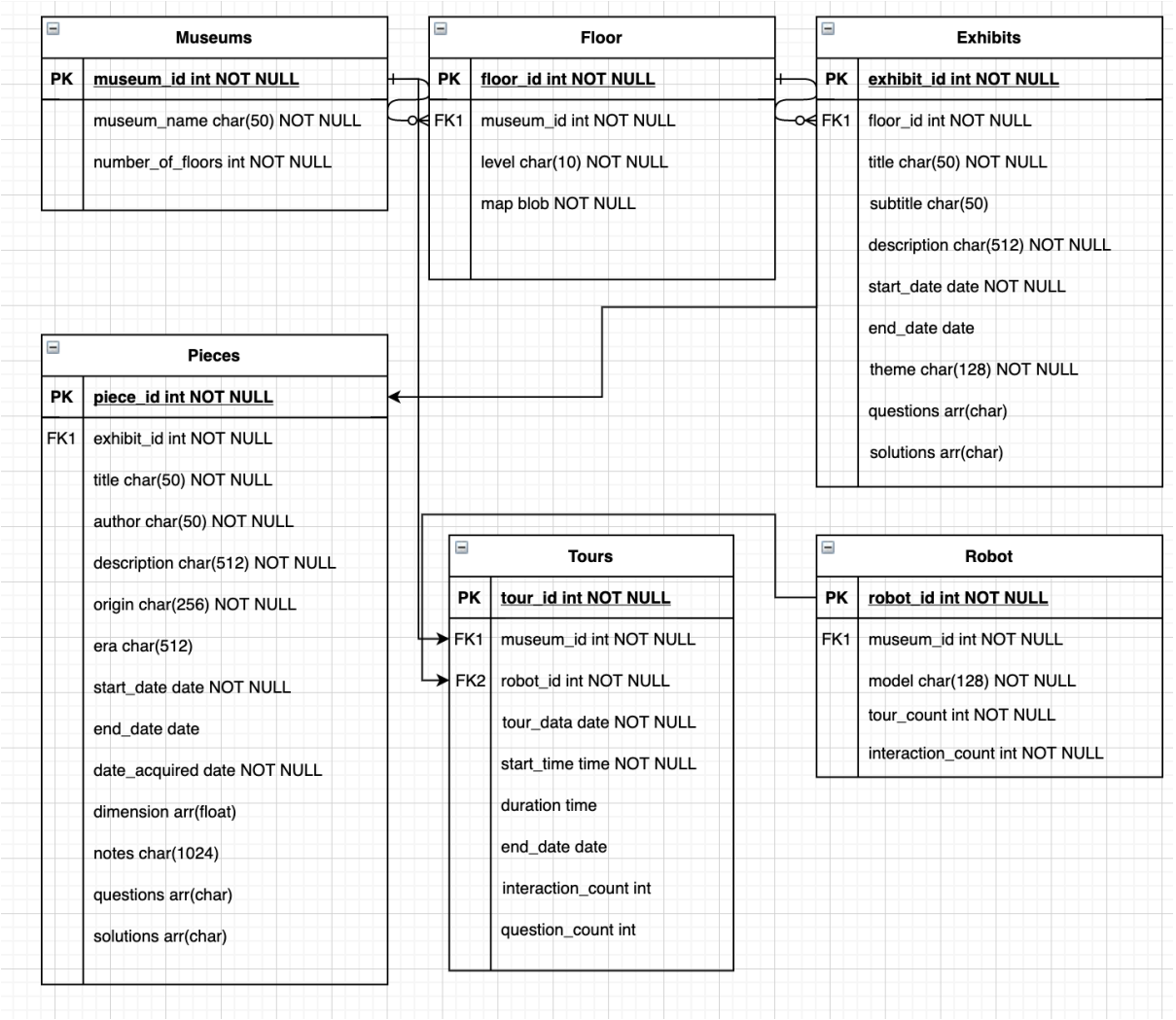


Fig. 5: The Database diagram provides all the database structures and tables needed to fulfill the project goals.

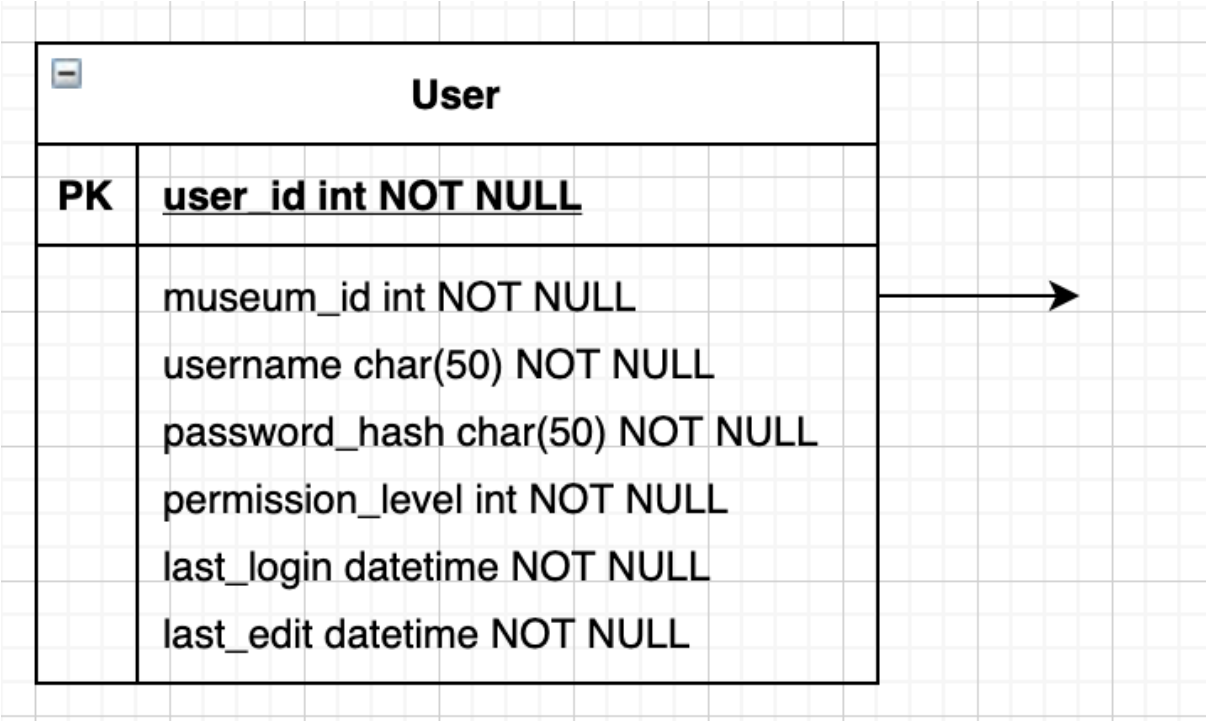


Fig. 6: The Database diagram provides the information necessary for User login. Moreover, the museum id links to the museum table from the previous figure.

Section 4.3 - Updated Hardware Design

High-level Hardware Component Diagram

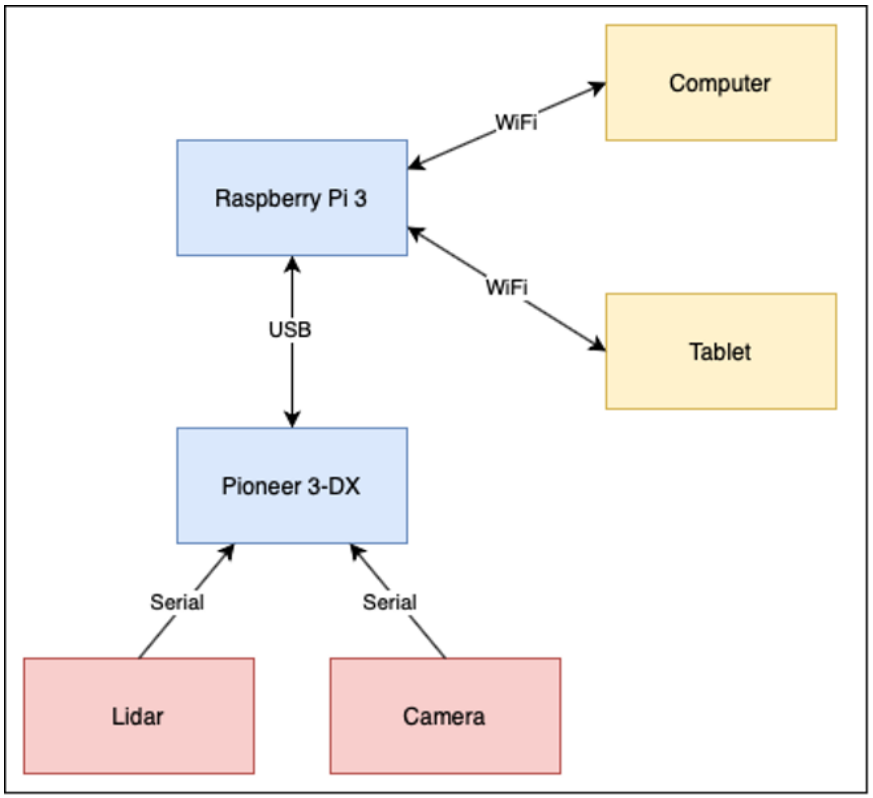


Fig. 7: Component diagram

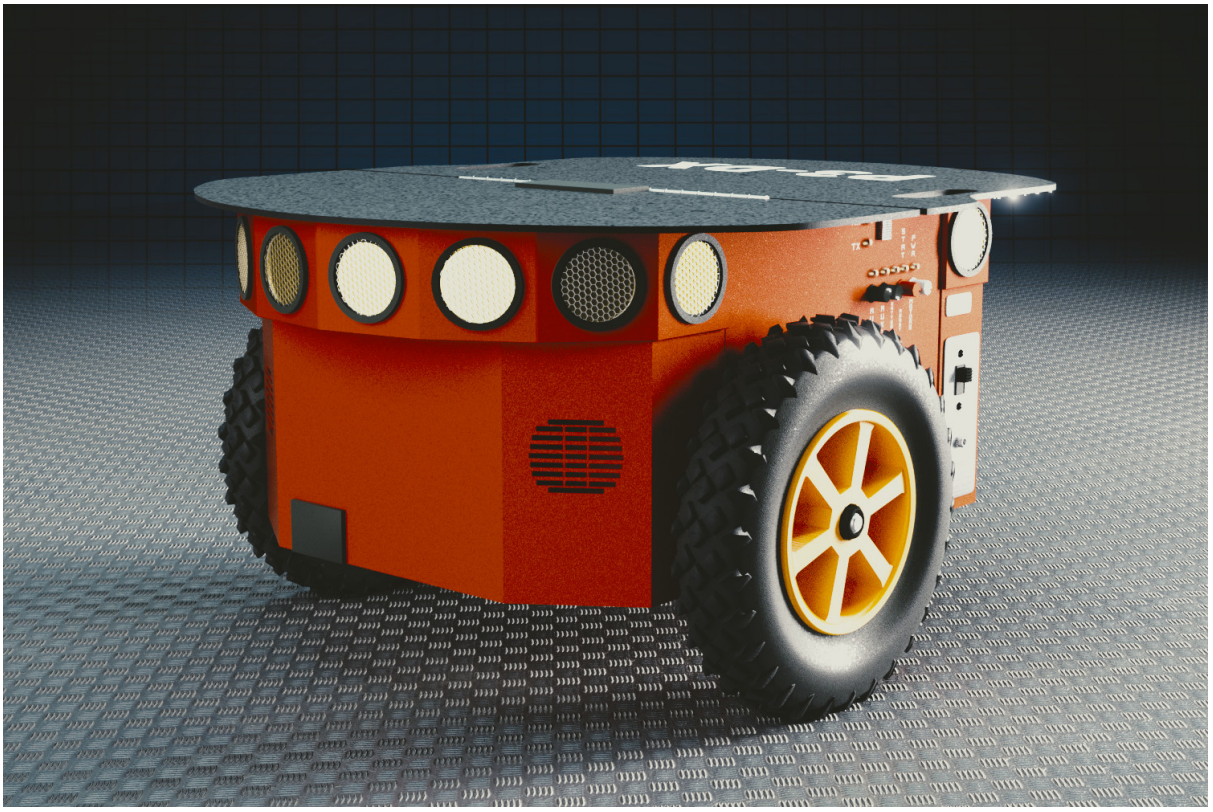
Blue: Control component
Red: Sensor
Yellow: User interface

Figure 8 illustrates the interactivity between the components. Section 6.2 will further elaborate what each component does. The entirety of the user interaction with the system will occur on the computer and the tablet. The computer will host a web application where museum staff can connect to the robot to upload information to the robot, and the tablet will be used as a physical interface for museum goers to interact with the robot.

Potential components

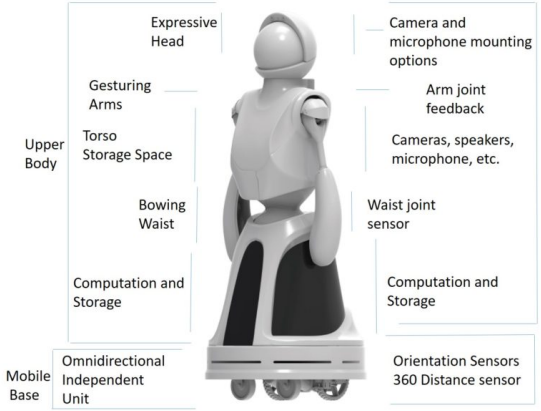
Pioneer 3:

One of our main components is the robot. As of now, our team currently has access to the Pioneer 3 robot; however, there is a chance that we will work a different robot such as the Quori mentioned below. This robot doesn't look as friendly or cool as the Quori.



Quori:

We hope to acquire the Quori robot, an open-source robot with an emphasis on human interaction. The Quori platform will allow for more expressivity and a more sociable museum experience, which is ultimately the goal of this project.



Section 4.4 - Updated User Interface

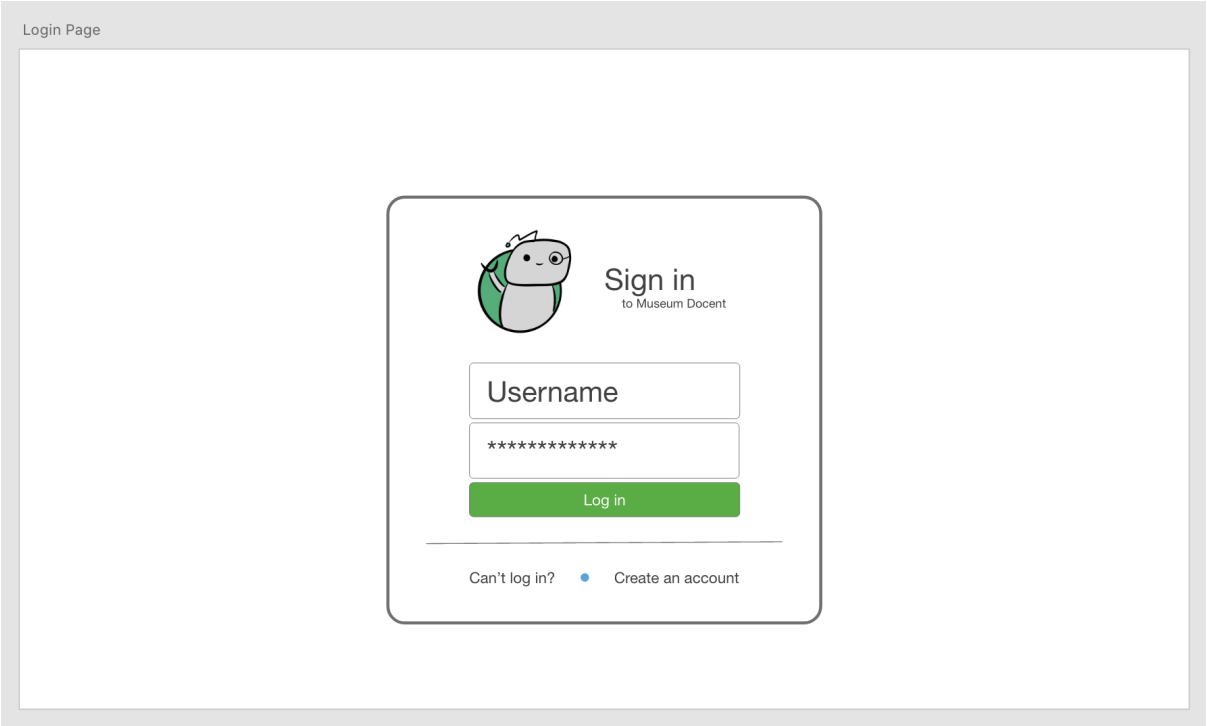


Fig. 8: The login page. Only museum staff members with special privileges should be able to access and edit the museum information in the robot; thus, it is natural to have a simple login where staff members can verify their credentials. The "can't log in" button will take the user to an alternate page where they can input their email address to reset their password. The "create an account" feature will enable users to input their manager's email, so they can ask for permission to edit the museum exhibits.

Fig. 9: The home page. This is the first page that the user interacts with after logging in. Here, the user can quickly glance at recent changes to the museum exhibits, updated analytics concerning the robot, and a way to enter the editing platform.

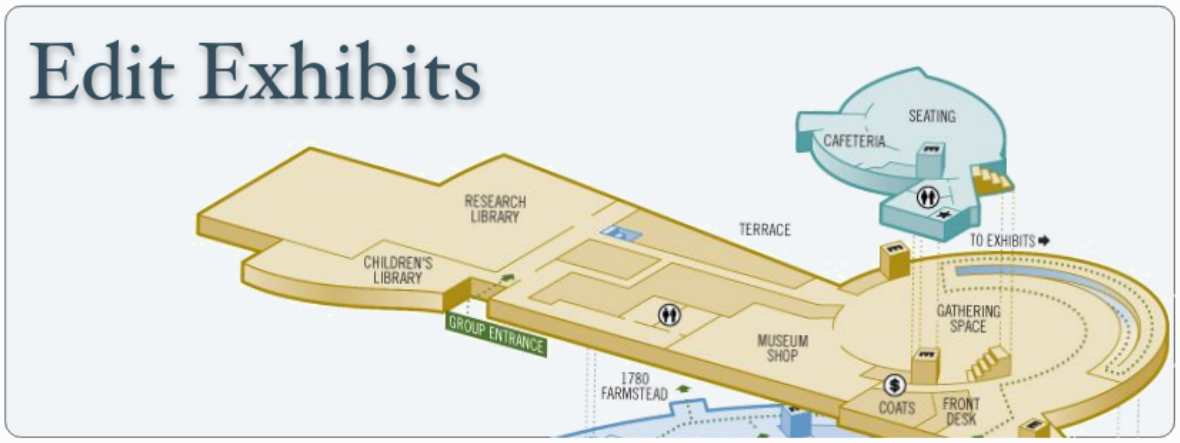


Fig. 10: The museum map button. As a component of the home page, the museum map button serves as a way to enter the museum editing platform.

Fig. 11: The last edit history. Since museums are managed by different individuals, it will be handy to know when someone last edited an exhibit. The component will display who last edited along with some information concerning what they have edited. When the user clicks the edit, a modal will open that specifies the exact changes that have been made.

Fig. 12: The short analytics component. This component focuses on providing the user with some quick statistics and analytics about the museum. For example, this area will display the amount of questions asked to the robot and the robot uptime and battery life. Here, the user can also interact with the component to see statistics about various times (last month, last week, etc.).

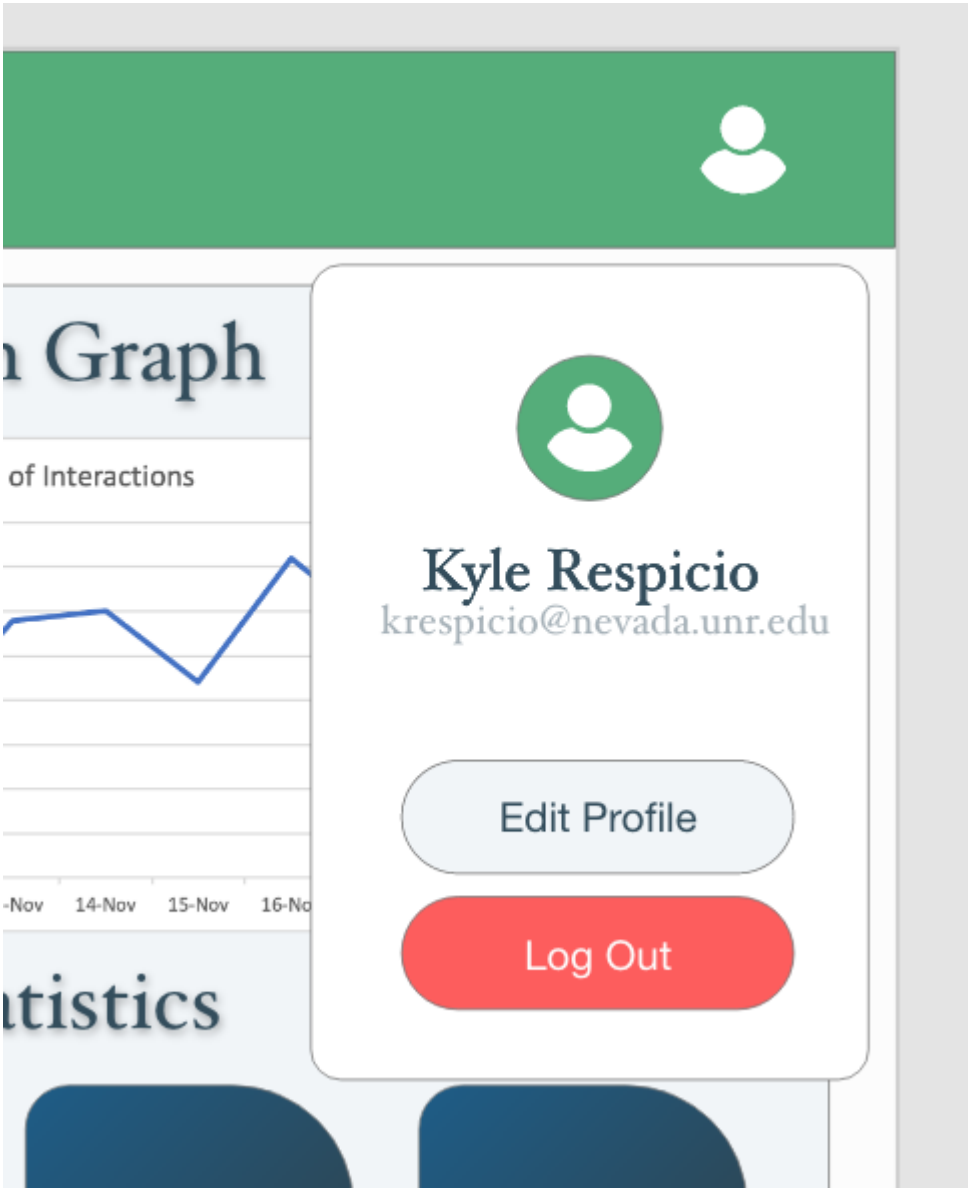


Fig. 13: The profile dropdown. Clicking on the profile button on the top right corner of any page will open a dropdown menu where the user can perform different tasks such as logging out or bring up an option to enter their profile page. This dropdown also displays the user's name along with their email address.

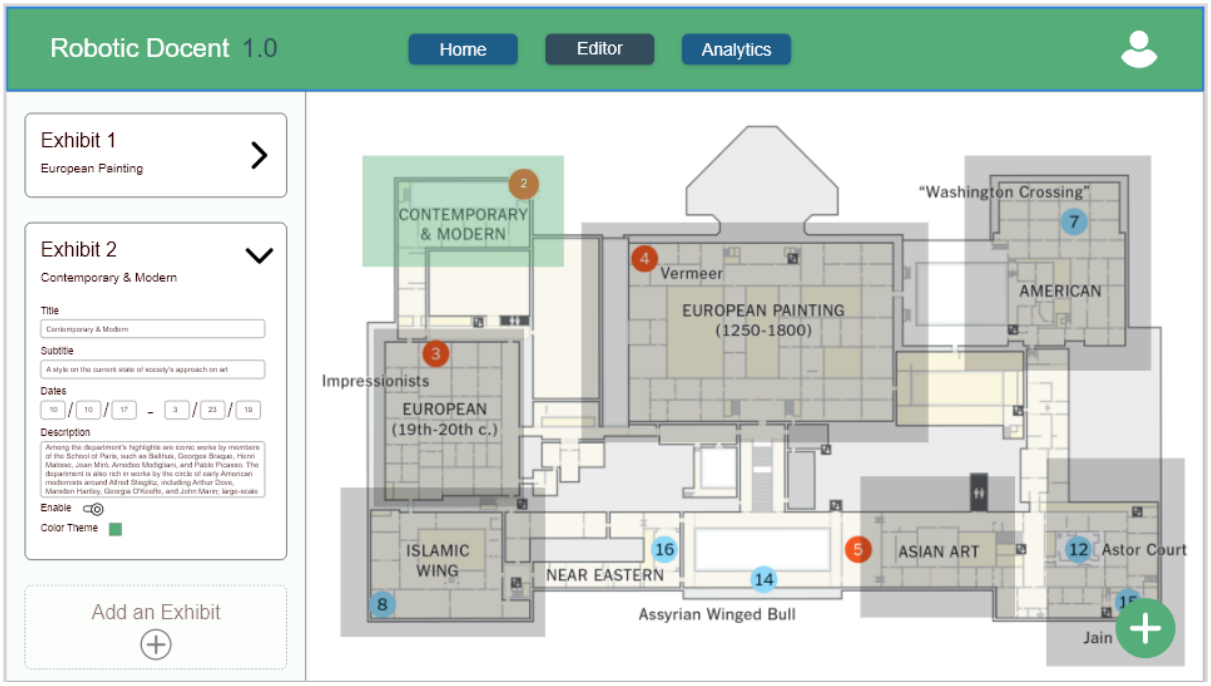


Fig. 14: The editor page. This is the main page where curators, directors, and docents will work on to review the current map layout with exhibits being highlighted in colors based on currently opened exhibits and dimmed gray with other existing exhibits. Here they can add, remove, and update the exhibits and pieces.

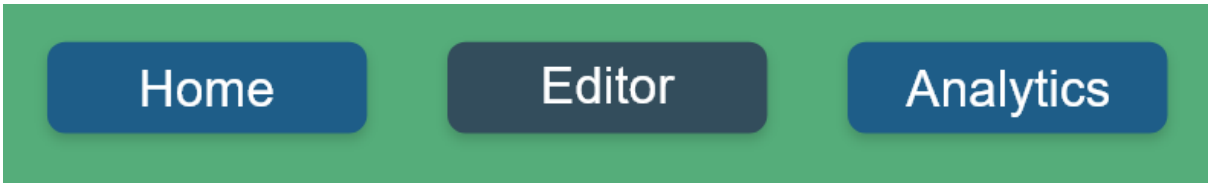


Fig. 15: The navigation bar. The bar indicates which page the user is currently on based on the differing color. For this figure, the navigation is set on the editor page. And it allows for easy navigation to the separate pages.

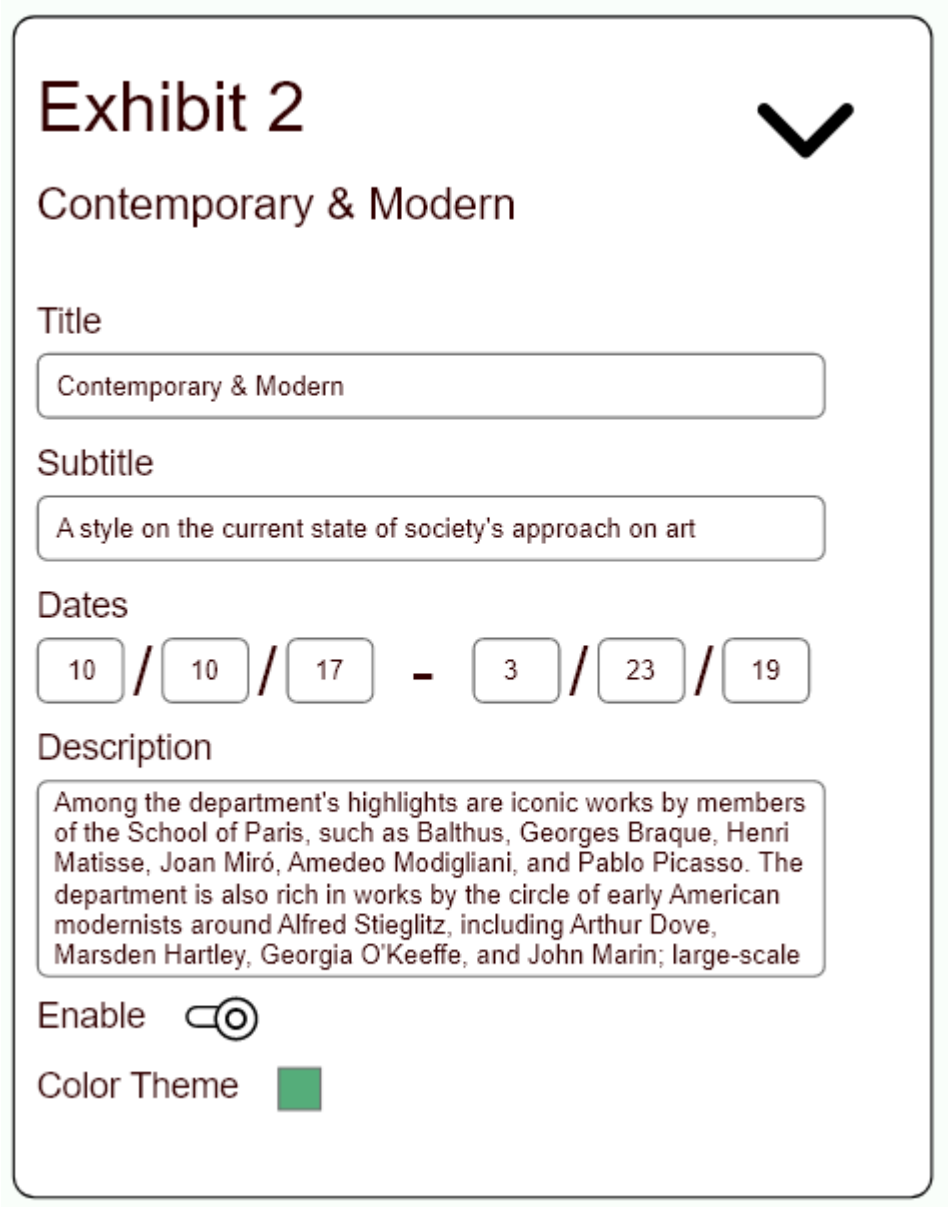


Fig. 16: The exhibit dropdown content manager. This section allows for editing information for each exhibit within the museum based on title, subtitle, dates the exhibit will be up, description of the exhibit, the color theme on the map, and the enable button to determine whether the exhibit should be available.

Fig. 17: The add exhibition button. At the bottom of the exhibit sidebar under all current exhibitions, the button allows adding current or future exhibits into the museum space. For a signifier, when the user hovers over, the button will extend out of the page slightly.

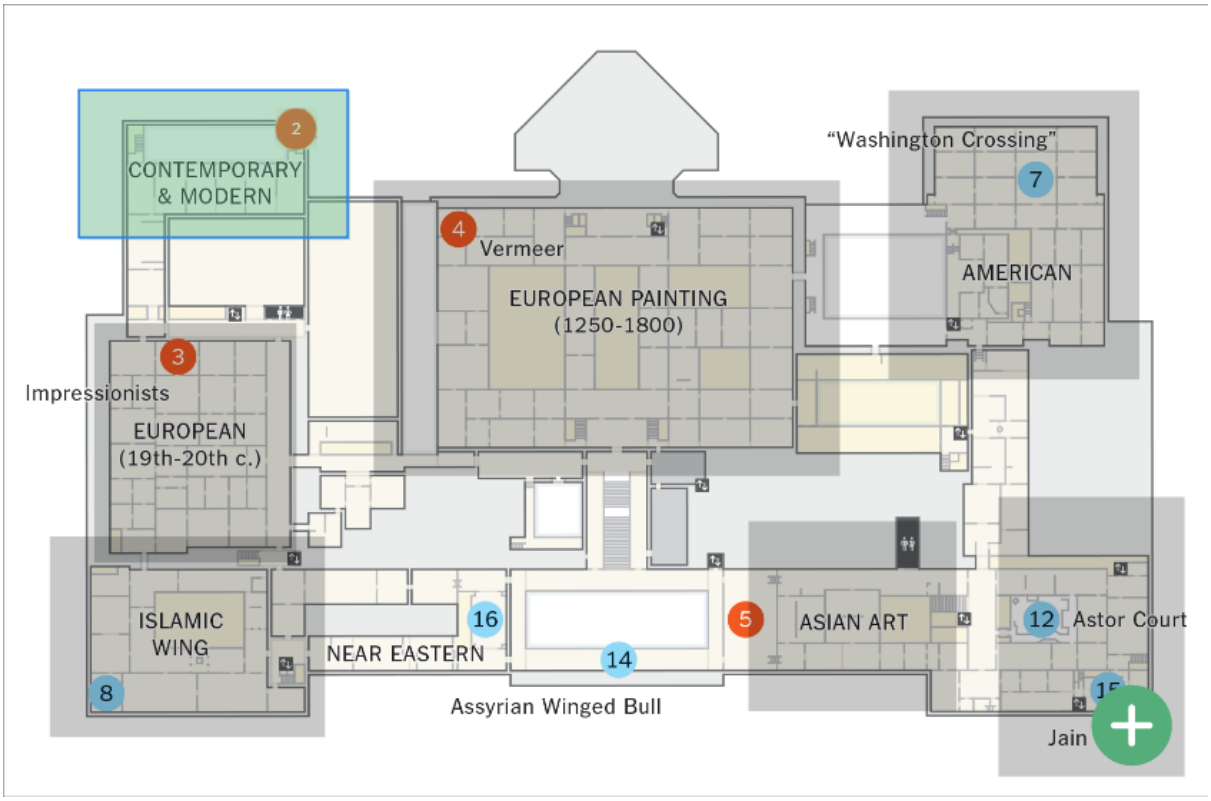


Fig. 18: The map layout. Here users can select certain exhibits based on the dimmed boxes surrounding each exhibit to move around. They can also select specific pieces within the exhibits to move around and indicate where the robot can navigate to and avoid as an obstacle.

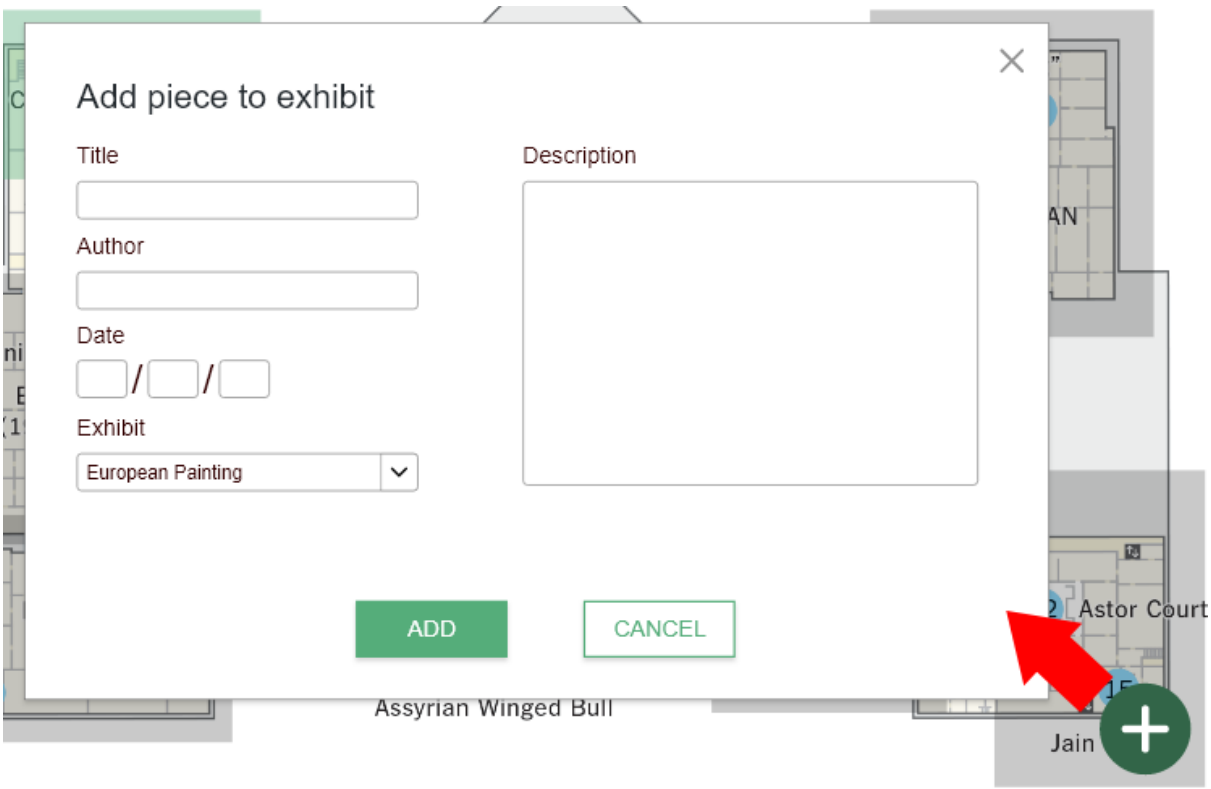


Fig. 19: The piece adding button. The green button at the bottom right corner when pressed will open a modal with form fill-out to add a new piece to the exhibit with information like the title, author, date created, description, and the categorized exhibit.

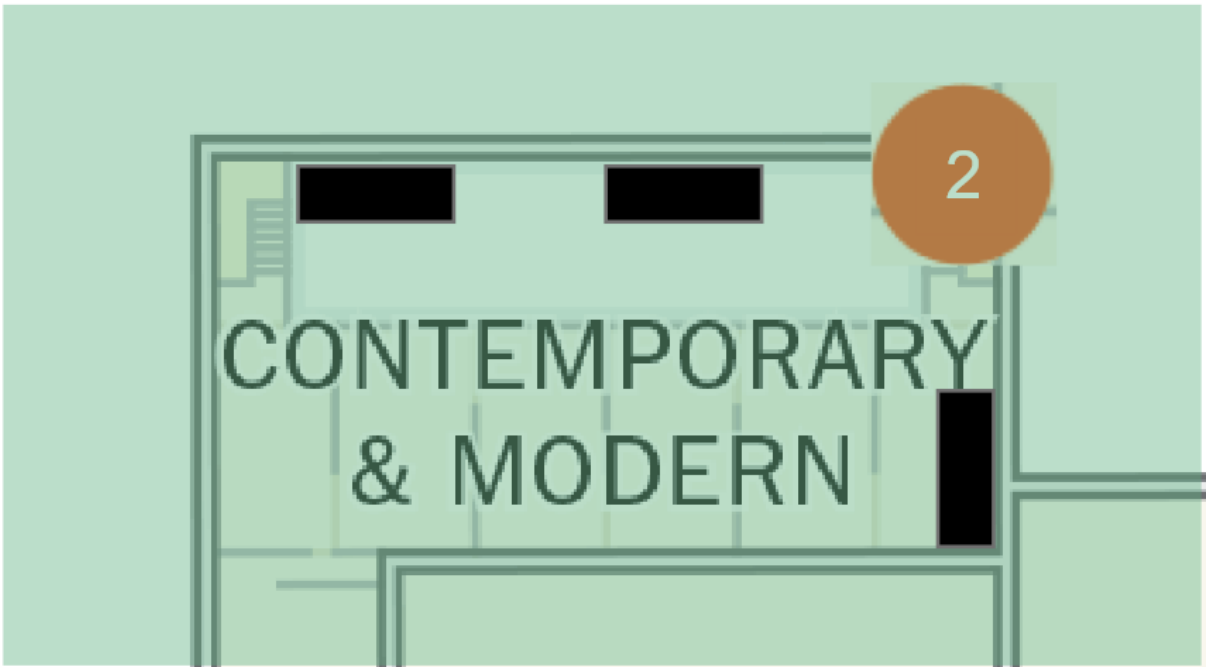


Fig. 20: The close-up exhibit. This interface allows the user to move the pieces within each exhibit to show obstacles and mapped information to the robot based on drag and drop

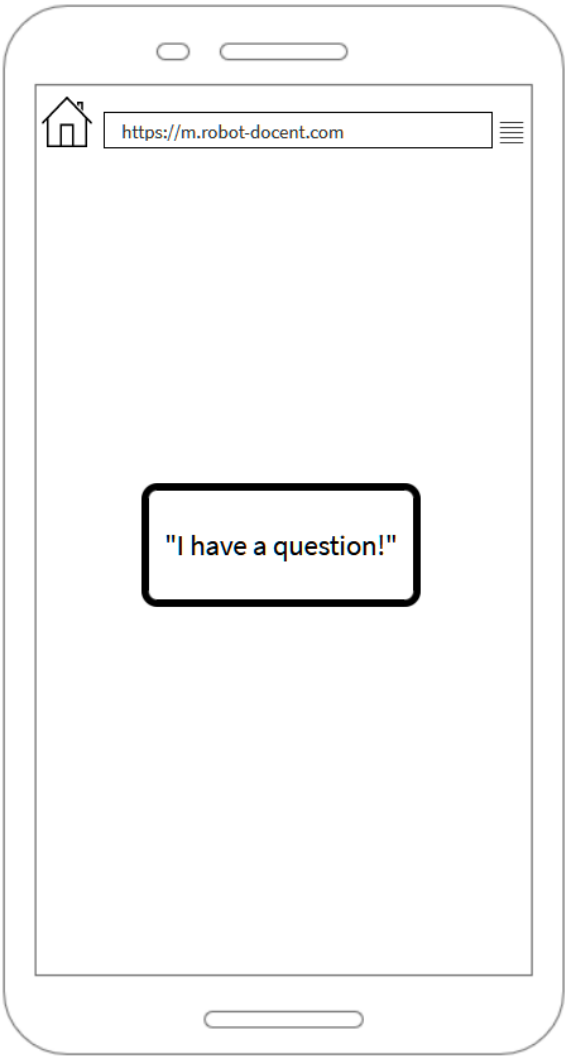


Fig. 21: The mobile website, at its core, will enable users to ask questions to the robot during the tour. This simple button can be pressed to ask the robot a question.

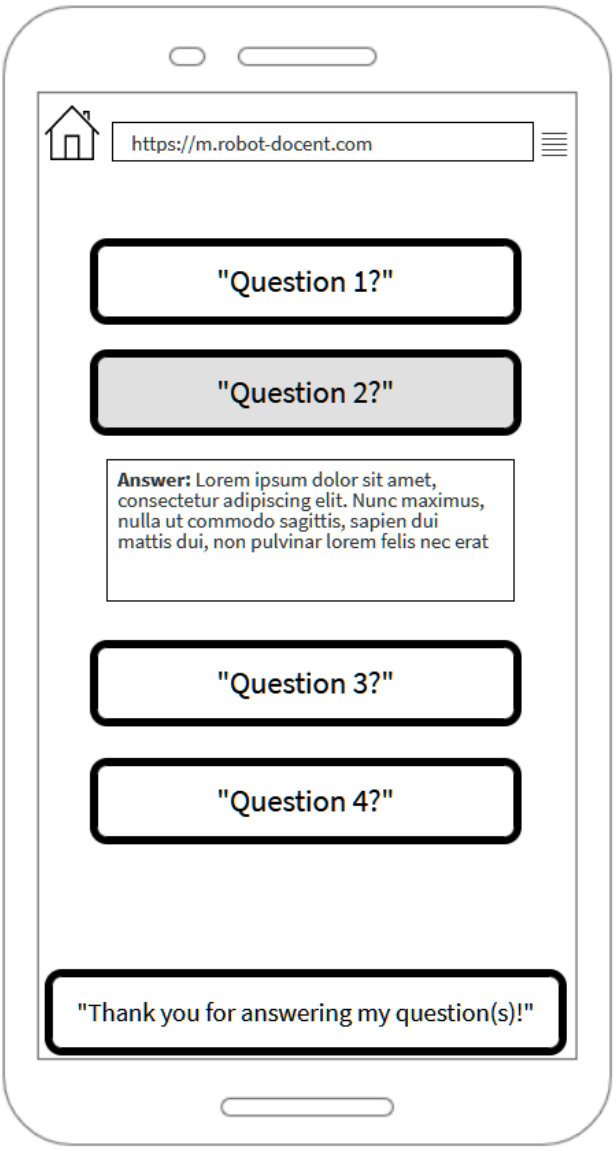


Fig. 22: The mobile website will also indicate how many questions are currently in the queue and how they will be answered by the robot. In most cases, a predetermined response will be outputted.

5 Updated Glossary of Terms

ADA	ADA refers to the American Disability Act of 1990. This act determines regulations for public bodies to prohibit and minimize discrimination based on disabilities.
API	API stands for application programming interface, which eases the interactions between two separate pieces of software. An API serves as a guidebook of possible interactions with a software component.
Autonomous	An object that is autonomous can perform tasks without external influence. The object can self-govern its actions.
Constraint	A restriction on a robot's movement that shrinks the possible motions to complete a task (Trebaol, 2019).
Continuous Path	The process of robotic traversal where the robot is controlled across the whole path rather than discrete points seen in point-to-point traversal (Robotics Glossary).
Controller System	A robot's controller system holds the appropriate data, applications, and logic to make the robot functional.
Curator	A person who determines and picks the items presented in a museum exhibit.
Degrees of Freedom	The number of different independent movements a robot can make. For positioning, three degrees of freedom are needed (up/down, left/right, backwards/forwards).
Docent	A person who guides visitors through a museum.
Exhibit	A public display of collected items, which typically has some theme connecting everything.
Graphical Interface	A system of interactive visual components.
Keck Museum	The University of Nevada, Reno's museum

	focused on fossils, minerals, and mining.
Lilley Museum of Art	The University of Nevada, Reno's museum focused on art to enhance the cultural life in Reno.
Noise	Visuals or sound that robotic inputs collect, but do not have any meaningful contribution. For example, background noise when a person is trying to speak to the robot.
Path Planning	A technique used to determine a valid sequence of motions to get a robot from a starting position to an end position (Trebaol, 2019).
Proximity Sensor	A non-contact sensor that is able to detect when objects are close.
Real Time System	The system performs tasks right when the task is asked for. The system is very concerned with time constraints.
ROS	ROS stands for Robot Operating System. ROS is an open-source library that helps developers build robotic applications.
Robot	An autonomous machine that is capable of handling different tasks and actions. For example, a robot could move around a room to find a light switch and turn the lights off.
Robotic Sensing	The topic of adding the five senses to a robot to make it more human-like.

6 Engineering Standards and/or Technologies

Robot Operating System (ROS)	ROS is an open-source framework that provides services to act as a meta-operating system. This includes low-level device control, message passing, and package management. ROS will serve as the backbone of our project by providing a means to operate the robot autonomously, communicating with museum goers and the database, and being manually operated by museum personnel.
Pioneer 3-DX	The Pioneer 3-DX is a research robot that is compatible with ROS. Its small and customizable build is ideal for testing the project in real life. The Pioneer 3-DX will be the robot we will use for both physical testing and demonstrations.
ROS Standards	These are a set of standards documented on the official ROS website on proper development guidelines. This includes code layout, packaging, building, and proper debugging and testing procedures. These are the main standards we will be using to structure the robotics side of the project in order to guarantee easy legibility to future developers of our project.
JavaScript	JavaScript is a scripting language That is used in conjunction with HTML and CSS. It allows for more complex and intricate website design for dynamic content. Javascript will be the main language for the web side of our project and will be used in conjunction with React.
React	React is a JavaScript library for creating interactive UI in an intuitive and painless way. It provides a component-based structure that efficiently updates and renders websites. React will be the major library we will use to create the web components of the project such as interacting with the robot and museum personnel.
React Design Principles	These design principles are the standards laid out by the official React website. These include focusing on stability, resist adding features, and scheduling. The React Design Principles will be the main standards we will be using to design the web components of our project to maintain a clean and well-functioning web app.

7 Project Impact and Context Considerations - Sherman

In terms of public needs, the project is intended to focus on the health and safety aspect through using a robot tour guide as the stand-in guide for participants and attendees to safely navigate the museum and minimize COVID-19 spread. This project hopes to also support museums in being more inclusive with other groups that may have been indirectly discriminated against. The project will help create an impact in upholding more ADA guidelines and protocols with the robot being utilized. The project is intended to mainly impact museum spaces on a cultural and social scale; robots will change the dynamic of how museum goers conduct themselves when receiving tours and their interactions specifically with the robot. In addition, the robot will also affect the social interactions between other museum goers within the space since there is a shift in power taken from a human tour guide, with the replacement of the robot, and to the goers.

8 Updated List of Project References

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9 Time Worked on Project Concept

Matthew worked a total of 1 hour on the engineering standards and technologies and updated glossary terms.
Guillermo worked a total of 1 hour on the updated specification.
Sherman worked a total of 1 hours on project impact and context considerations, abstract, and formatting.
Kyle worked a total of 1 hours on updated design.