# Boston University
# Electrical & Computer Engineering
**EC463 Capstone Senior Design Project**

# Problem Definition and Requirements Review

# MuseumMate

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**Customer Sign-Off** ________________________________________

# MuseumMate

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# Project Summary


The platform to be developed is MuseumMate, an indoor navigation and exhibit interaction system designed to deliver precise navigation information and exhibit-related multimedia to visitors of a museum. Upon entry into a museum implementing MuseumMate, individuals are given a small handheld device, dubbed the TourTag, which detects Bluetooth Low Energy (BLE) signals emitted from beacons placed around the museum and transmits the measured signal strengths to a server. The server uses this data to compute the location of a specific user and stores it in a database, which is referenced to perform precise and efficient navigation of a user upon request by use of a web application. Furthermore, RFID tags are placed on each exhibit and are automatically scanned by TourTags in close proximity, giving more precise location information to the system and allowing nearby users to automatically view additional multimedia from the scanned exhibit through the web application.

# 1 Need for this Project

Nowadays, museums have become not only the forerunner of history preservation, but also a key venue for enjoying art. Visiting museums has become a premier leisure activity and in regions with a plethora of museums, such as Boston, every individual, ranging from the casual first-time visitor to the museum aficionado, is able to find a museum that they deeply cherish. Museums are aware of their appeal and make great efforts to maintain their exhibits and develop new media to provide innovative experiences to their visitors. Nevertheless, much of this media is left unused since the average museum visitor does not come into contact with everything available. Furthermore, the unfamiliar layouts of museums can cause museum visitors to get overwhelmed by overcrowding and disoriented as they try to navigate to exhibits. MuseumMate will address these issues by providing precise navigation and a system to display multimedia to its users.

MuseumMate aims to improve efficiency in all museum visits by giving the visitors the ability to plan museum trips beforehand, or in real-time, and by allowing museums to maximize their informative capabilities by giving them new and effective ways to reach their visitors. The system will use Bluetooth Low Energy (BLE) beacons to obtain positioning data of each visitor. Real time navigation based on the collected information will then coordinate the flow of traffic in the museum on the fly, allowing users to maximize their time spent viewing what they came to the museum to see and minimizing bottlenecks created by congestion. The location information collected for every user can also be studied to allow museums to optimize their layout to avoid bottlenecks based on the peak activity at various exhibits or rooms and at what time of the day this occurs.

MuseumMate will provide unique IDs to every exhibit through the use of RFID tags, which will allow museums to greatly enrich the experience of their visitors by giving them access to a vast store of multimedia that is currently underutilized through a combination of RFID technology and a web application. Furthermore, with RFID technology, users will be able to view information about any exhibit in various forms including text-to-speech and subtitled videos, making them accessible to all people, including those with physical impairments.

# 2 Problem Statement and Deliverables

## 2.1 Problem Statement

The dominant issue that our proposed system aims to tackle can be split into three subsections: congestion in museums due to irregular museum layouts and bottlenecks created by popular exhibits or sections, the lack of engaging and interactive media about exhibits, and the scarcity of tools that promote accessibility in museums.

Our proposed solution to tackle this issue involves designing portable user devices, dubbed TourTags, which incorporate BLE sensors to passively detect BLE signals from beacons, and RFID scanners to utilize RFID tags on exhibits for unique identification of individuals and accurate user location tracking. The information gathered will be sent to a server for processing and storage in a database. Finally, users will use a mobile application that communicates with the aforementioned server to retrieve data from the database to provide routing guidance within the museum and displays exhibit-related media obtained from the museum's collection of multimedia based on RFID scans.

## 2.2 Deliverables

Our system will consist of the following hardware components:

- A handheld device, the TourTag, with the capability to scan BLE and RFID signals and send these signals to a server
- BLE beacons, allowing the system to trilaterate the position of each user
- RFID tags on each exhibit, providing automatic access to multimedia and additional location information
- A Raspberry Pi, housing the server and backend functionality of the system

Our system will also consist of the following software components:

- A server, enabling the system to process raw data obtained from TourTags and facilitating data flow between the databases and the user
- Databases, serving as storage for location information and exhibit multimedia
- A mobile application, providing a medium for users to view exhibit multimedia and obtain navigational information from the server through the internet

# 3 Visualization

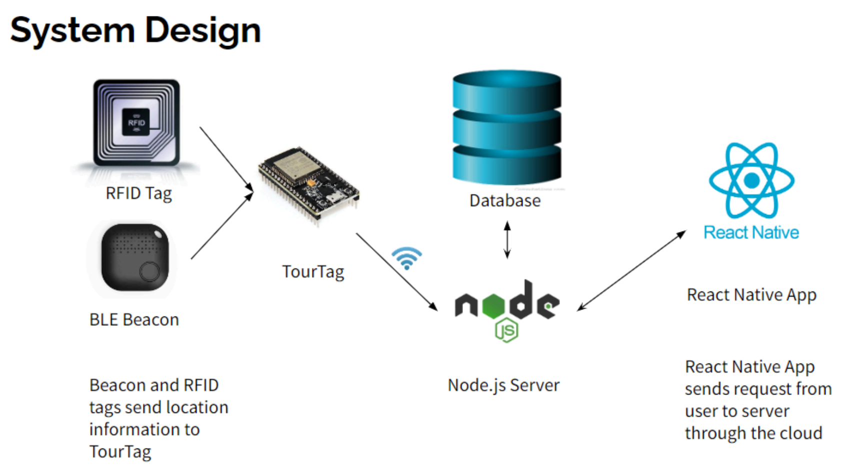


*Fig 1. A representation of the overall architecture of our system*

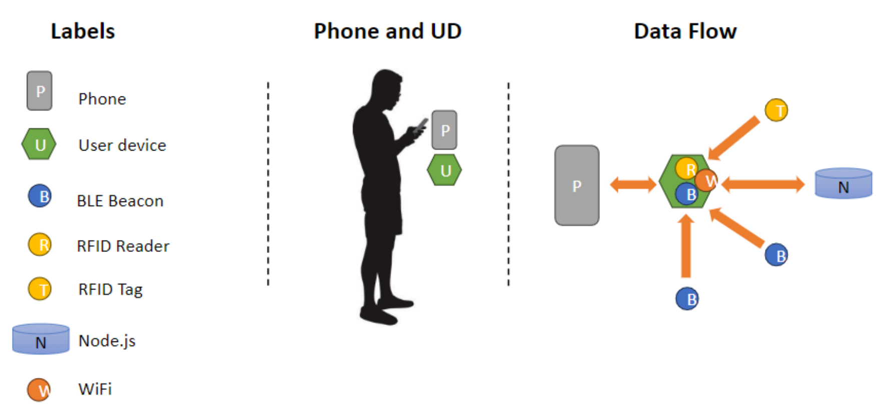


*Fig 2. A diagram depicting how data flow occurs with the interaction of various technologies*

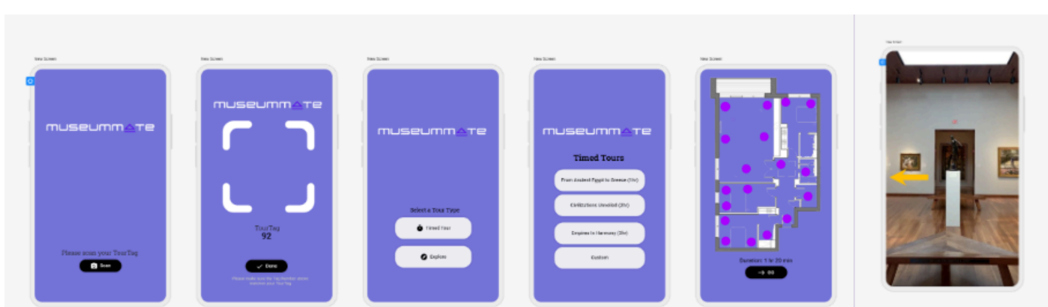

*Fig 3. A Wireframe representation of some of the various UIs displayed to users on the mobile application*

# 4 Competing Technologies

Navigine's technology offers a multi-faceted approach to indoor location services within museum environments. Their indoor navigation system provides real-time positioning and guidance for visitors, mitigating the challenges of navigating expansive indoor spaces. When integrated, as a user approaches specific displays, the system can deliver supplementary data or multimedia content to portable devices. Furthermore, the system can algorithmically generate routes based on inputted preferences, aiming to optimize individual visitor experiences. From an administrative perspective, the system provides analytics derived from tracking visitor movements, offering data on exhibit engagement, visitor density patterns, and overall traffic flow. Such data can be pivotal for logistical planning and resource allocation. In terms of safety protocols, the technology has the capability to direct visitors towards designated exits during emergency scenarios. Additionally, the system supports location-triggered notifications, enabling context-specific communications, though its application needs careful consideration to maintain the primary educational and experiential objectives of museum spaces.The one feature that Navigine doesn’t implement is congestion control. The navigation service takes you the shortest route based purely on distance, so there is a strong possibility of the route taking a guest through crowded areas and increasing the time it takes the guest to navigate the museum.

# 5 Engineering Requirements

This section breaks down the engineering requirements per associated subsystem.

### 5.1 Mobile Navigation Application

Functional:

1. Multimedia content (audio, video, text) sourced from URLs. In this scenario, "multimedia" refers to audio-visual elements inclusive of text.
2. Enables navigation using a comprehensive museum map, which includes all floors, whether this be with distinct turn-by-turn indications or indicative arrows. "Navigation" in this context is providing a pathway guide to users.
3. Depicts current traffic through a potential heat map representation. Here, "traffic" refers to the concentration of visitors in a certain area.
4. Calculates the most direct route from a user's present location to a chosen exhibit, adjusting for room densities. Furthermore, it should provide consecutive directions to the next museum spot.
5. Graphically showcases the user's instantaneous location on the museum map.
6. Interface can be accessed through web browsers or as a standalone application.
7. Equipped with a diagnostic function, but exclusively in an elevated user mode.

Performance:

1. Time taken for route determination should not exceed 3s.
2. The map's display time must remain under 3s.
3. Any alterations in navigation should manifest in less than 2s.

### 5.2 Routing Algorithm / Server

Functional:

1. Amass the journey data for each unique device (UD).
2. Procure the positional data of every UD.
3. Record the duration each UD spends at particular exhibits.
4. Retain all route computation requests made by users.
5. Generate traffic heat maps intended for dissemination to smartphone apps.
6. Keep a detailed log of all UD interactions, meant for diagnostic and troubleshooting purposes.
7. Facilitate the extraction of collected data in .csv format for insightful analysis.
8. Respond to shortest path requests initiated by the mobile navigation application.
9. Host on either local networks or a cloud-based system.

Performance:

1. System should be capable of supporting as many as 512 UDs.

**5.3 Indoor Positioning Function**

Functional:

1. RFID is the source of positional estimation. Here, "RFID" pertains to Radio Frequency Identification.
2. BLE (Bluetooth Low Energy) also serves as a means of positional estimation.

Performance:

1. Positional updates on a UD should be made every 10s or faster.
2. RFID should offer positioning accuracy within 1m in all cases.
3. For BLE, the basic expectation is to pinpoint the encompassing room accurately in every scenario.
4. Typically, BLE's position accuracy should be within 4m for 90% of cases.

**5.4 User Device**

Functional:

1. Device interfaces seamlessly with the user's smartphone.
2. Efficiently reads signals emitted by BLE beacons.
3. Scans and identifies RFIDs present at exhibits.
4. For localization, it relies on at least one BLE beacon for proximity and multiple beacons for precise positioning.
5. Facilitates communication between itself and the user's smartphone regarding positioning and RFID scans.
6. Can be recharged after usage.

Performance:

1. A minimum of 4 UDs should be produced.
2. Production cost per device should remain below $50 when made in batches of 1000.
3. Should function continuously for over 12 hours post a full charge.

# 6 Appendix A References.

[1] Navigine, "Navigine," [Online]. Available: https://navigine.com/. [Accessed: 19-Oct-2023].

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[4] Espressif Systems, "Getting Started with ESP-IDF," [Online]. Available: https://docs.espressif.com/projects/esp-idf/en/latest/esp32/get-started/. [Accessed: 19-Oct-2023].