Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Manila

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by

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This thesis hereto entitled:

SMART DIRECTORY MAP LOCATOR WITH NAVIGATION USING A* ALGORITHM FOR THE NATIONAL MUSEUMS IN MANILA

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– The
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ABSTRACT

Different techniques and algorithms have been created for solving difficult problems. The A* algorithm is one of these techniques that has been used in many different applications that call for quick decision-making. Route planning, video games, robotics, and many more industries may benefit from the use of this algorithm. Importantly, it can be used to determine the fastest and shortest path between two points, helping people quickly find their way around complex structures such as shopping malls, airports, hospitals, and museums. This efficiency is especially valuable in large venues where traditional signage might be insufficient and difficult to understand.

By providing a quick and easy way to navigate around large structures such as the National Museums of Manila, this study aims to improve the overall experience of visitors and make it easier for them to explore and easily find certain sculptures, paintings, artifacts, etc. Unlike outdoor GPS (Global Positioning System), which doesn't work well indoors, the suggested system makes use of the A* algorithm to provide intelligent route planning capabilities and optimizing paths according to visitor preferences. Real-time data combined with a user-friendly interface makes it easier for visitors to find their way around the museums, find specific exhibits, galleries and learn about the cultural and historical significance of these artifacts. The implementation of A* algorithm for smart navigation not only enhances the overall visitor experience but also contributes to the promotion of National Museums in Manila and its cultural heritage.

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CHAPTER I

THE PROBLEM AND ITS SETTINGS

The museums located in Manila usually cover a large area, making it difficult for new visitors, and staff members to navigate. For directions within as well as outside the museums, physical maps or satellite navigation tools like Google Maps are frequently used. These maps are insufficient for the interior navigation, as they do not show the locations of specific gallery halls, or office buildings in museums. There are online virtual museum tours available online, and they provide a panoramic viewing experience, complete with arrow buttons for navigation and the option to access information about specific artworks. However, the current navigation can be challenging, as visitors must proceed sequentially through the tour, making it difficult to return to specific locations of interest within the vast museum space. Furthermore, the museum staff might not always be able to provide precise guidance to locate specific artworks, leaving visitors with an inefficient way to find the art they want to see.

The best solution to these problems would be to create a museum navigation system that is tailored to the museums in Manila itself (Fine Arts and Anthropology). The proposed museum navigation system may be utilized online and is accessible via mobile devices, making it possible to employ navigation at any location within the premises, thanks to advancements in technology. The system is expected to be used as an alternative means of locating the museum's hall galleries, and offices. The system will use the A* algorithm and 2D mapping as the primary features to provide more accurate searched places.

BACKGROUND OF THE STUDY

The central museums of the National Museum of the Philippines are collectively referred to as the National Museum Complex under Republic Act No. 8492, often referred to as the 1998 National Museum Act. It designated the Executive House Building (formerly known as the Old Congress Building), the Department of Finance Building, and the Department of Tourism Building located in Rizal Park's Agrifina Circle as the official venue of the National Museum (National Museum Act of 1998, 1998). Republic Act No. 11333 allowed the National Planetarium, which has been operated by the National Museum since 1975 (now closed) and is located in Rizal Park, to be a part of the National Museum Complex (National Museum of the Philippines Act, 2019). The mentioned buildings would be converted into distinguished museums (National Museum Act of 1998, 1998). The Executive House Building was converted into the National Museum of Fine Arts (opened in 2000), the Department of Finance Building into the National Museum of Anthropology (opened in 1998), and the Department of Tourism Building into the National Museum of Natural History (opened in 2017).

Having three (3) national museums with each housing many galleries, a typical visitor or tourist would not be able to familiarize themselves with the museums and the halls immediately. The National Museum Complex spans a wide area, making it difficult for new visitors, tourists, and staff members to navigate. Physical maps, satellite navigation tools, and the online museum virtual tours are insufficient in providing a more efficient and optimal indoor navigation needed for these museums. With this, the researchers thought of utilizing technology into making a 2D digital wayfinding map that is easily accessible to visitors. The proposed project would use the A* algorithm in finding the optimal path from one point to another, and would integrate a searching feature that let the users find the specific art/sculpture/artifact or gallery they wanted to find.

Technologies for wayfinding and navigation play a critical role in enhancing people's quality of life. Many use a number of devices and applications on a regular basis to track their whereabouts and provide them helpful information as they move around cities and within buildings (Prandi et al., 2021). Wayfinding research has led to various algorithms that compute the shortest, quickest, or even simplest routes between two points (Haque et al., 2007). One of the most well-known path algorithms is the A* algorithm, which repeatedly explores the most probable undiscovered location it has found. It ends when a location explored is the target, otherwise, it records all of that location's neighbors for further exploration (Cui & Shi, 2010).

Mobile indoor navigation utilizes an interactive navigation system in a mobile device to navigate one's way around indoor areas in order to reach a desired location. An indoor navigation system can help a user to find their way through large buildings like museums without any difficulties or wasted time (Sakpere et al., 2017).

OBJECTIVE OF THE STUDY

General Objective

To develop a Smart Directory Map Locator with Navigation to aid the staff and visitors with navigation and provide them with the optimal route from one place to another. The application should provide an admin tool to maintain the artworks and gallery per museum. The admin can edit, remove, and save specific artworks/gallery. Users should be provided with a 2D digital map of two National Museums of Manila (Fine Arts and Anthropology) to visualize the entirety of the museums and properly see what routes to take inside a certain museum and the route to the remaining museums. Furthermore, using the A* algorithm, it should be programmed to take the shortest route to the designated area.

Specific Objectives

The study has the following specific objectives:

1) Design a smart navigation system with the following features for the users:
    a) User Log-in System
    b) Shortest Path (Employ the A* pathfinding algorithm to find the shortest route from one place to another)
    c) Average Distance and ETA (Estimated Time of Arrival)
    d) Filter for every floor
    e) View Gallery (list of all artifacts, artworks, sculpture, etc. per museum)
    f) Track Visitation Progress
2) Design an Admin tool with following features:
    g) Admin Log-in System
    h) Fine Arts Tab
    i) Anthropology Tab
    j) List of Galleries

k) Edit Function

l) Remove Function

m) Save Function

2) Create the map, where necessary information is provided. It includes:

a) Labels (e.g. Gallery V, Gallery VI, Exit, Restroom etc.)

b) Brief information about the galleries

c) Information about the art/sculpture/piece and artists

d) Establish a QR code to access the download link for the finished application.

3) Develop the actual mobile application using developmental tools.

e) Godot 4 – Game Engine (for 2D map digitalization, Main UI development, and routes optimization)

f) Firebase (for database)

g) Android Studio (for mobile application development)

4) Test and evaluate the system in terms of functional suitability and reliability.

5) Determine the level of acceptability of the developed prototype system using the ISO 25010 criteria such as functional suitability, performance efficiency, usability, reliability, and maintainability.

SCOPE AND DELIMITATION OF THE STUDY

The study will focus on developing a Smart Directory Map Locator with Navigation to help with navigation and guide users to their target destination with the correct route. The system is exclusively centered around two of the National Museums of Manila, Fine Arts and Anthropology, and does not extend to the other branches or museums. The target users of the system are staff members and visitors. Users can access the application through the QR code provided at every entrance of the National Museums, granting them access to the app and its functionalities. Users who do not want to access or use the application are excluded from the system’s scope and can’t access the application.

The navigation system’s functionality heavily relies on the A* algorithm for navigation and pathfinding, and alternative algorithms or navigation methods are not considered within its scope. It also tracks the progress of the user's visits (galleries/paintings/artifacts/sculptures already visited). Additionally, mapping of the national museums is limited to the individual buildings within the museum and does not extend to other areas or locations. Lastly, the system does not encompass other technological features or tools present within the museum, such as the online virtual tour.

SIGNIFICANCE OF THE STUDY

The result of this study hopes to benefit the following:

Staff. With the application, the staff will be more familiar with the museum's layout, which in turn will facilitate the visitors' seamless navigation of the premises.

Visitors. Visitors can effortlessly navigate the museums and enjoy the beauty of it without worrying about being lost. The system will also display information about each artwork, enhancing visitors' knowledge of the artwork and the artist behind it.

Future Researchers. There are so many tourist spots in Manila that can serve as their subject, and by making this study their foundation, they will be able to develop a more advanced system that aids all the individuals who seek to explore the places and allows them to fully savor the attractions.

CHAPTER II

CONCEPTUAL FRAMEWORK

This chapter provides an overview of related literature, related studies, the study's conceptual model, and the operational definition of terms relevant to this study**.**

REVIEW OF RELATED LITERATURE AND STUDIES

Indoor Navigation Systems

The word "navigation" refers to tasks that involve determining the user's position, selecting effective routes, and assisting the user as they navigate those routes in order to arrive at the desired destination. Many navigation systems were created in the past to facilitate access to both indoor and outdoor spaces. The majority of outdoor navigation systems employ the Global Navigation Satellite System (GLONASS) and GPS to determine the user's location. Meanwhile, due to non-line-of-sight (NLOS) problems, the GPS is unable to track objects with any degree of precision inside buildings. Although it may be overcome by utilizing "high-sensitivity GPS receivers or pseudolites," this restriction makes it difficult to use GPS in indoor navigation systems. The expense of implementation, on the other hand, may be an obstacle to using this technology in real-world circumstances (Kunhoth et al., 2020).

Applications for indoor navigation systems are numerous. Some applications are human navigation in train and bus terminals, malls, museums, airports, and libraries. Indoor navigation systems are beneficial to those who are visually handicapped as well. However, indoor navigation is more challenging than outdoor navigation. The interior environments feature a variety of barriers, making navigation systems more complex to implement. The three main modules that make up a human indoor navigation system are the indoor positioning system module, the navigation module, and the human–machine interaction (HMI) module. The indoor positioning system calculates the user's position, the navigation module determines routes to the desired location from the user's present location, and the HMI module facilitates user interaction and provides instructions. For indoor positioning, GPS-based ones are proven to be ineffective so techniques that involve computer vision, pedestrian dead reckoning (PDR), and radio frequency (RF) signals are used instead (Kunhoth et al., 2020).

Admin

There are several tasks when it comes to being an admin. An admin can be about business, network, system, etc. But an admin will most likely be related to technology, where an admin can organize, control and arrange specific information. An IT specialist who maintains an environment for multiple users and ensures ongoing, optimal performance for IT services and support systems is known as a system administrator, or sysadmin (Hanna, 2021). On the other hand, according to PagerDuty (2024), the individual in charge of setting up and overseeing a company's whole infrastructure, which includes all of the hardware, software, and operating systems required to support day-to-day operations, is known as the SysAdmin or systems administrator.

System administrators are mostly in charge of overseeing the whole lifespan of hardware and software assets, including licensing, updating, administering, and troubleshooting. This proactive function tries to prevent business downtime by addressing issues before they arise (Infosec Institute, 2023). Businesses rely heavily on the servers and systems, so it is important to ensure the operations run smoothly and never experience any downtime. For this reason, companies require system administrators. A system administrator makes sure internet servers and computer systems operate efficiently and detects and resolves any possible problems (Simplilearn, 2024).

To be a successful system administrator, one must, first and foremost, be proficient in the computer sciences and have an interest in the discipline.

2D Mapping

As the name implies, 2D mapping works with images or objects that have only two dimensions: width and length. However, various researchers define 2D in rather different ways. According to Schobesberger and Patterson (2007), 2D or conventional maps show the Earth's surface in an opposite direction from an imagined starting point that is directly overhead. The scale of two-dimensional maps is approximately the same in both the x and y directions. While Lewis (2022) and Crescent Flight Operations (2019) defined 2D mapping as something similar to Google Earth, where a drone is brought in to take hundreds or thousands of pictures, which are then stitched together and processed to produce a high definition map (a single file that can be viewed, tracked, or used for distance measurements). In contrast to a regular photo, an orthomosaic image is a collection of images that are taken and geometrically corrected to be uniform and scaled. Because it is an exact representation of the earth's surface, it can be used to measure true distances. To simplify, 2D mapping concentrates on using the x and y coordinate system only to represent a particular location on flat surfaces.

Several maps that are now available are two-dimensional (2D), so it's also crucial to remember that there have been studies done that compare 2D mapping to 3D or Augmented Reality (AR). According to a study by Weihua, et al. (2021), individuals using AR focused more visually on people and less on buildings than participants using 2D maps when it came to environmental factors. The routes that were sketched out revealed that AR users had more difficulty in remembering the route. Furthermore, in a study by Schobesberger and Patterson (2007), 208 participants completed a questionnaire to assess the effectiveness of 2D and 3D trailhead maps. The researchers discovered that while younger respondents and women preferred 3D maps, older respondents and men generally preferred 2D maps. In general, 48% of respondents preferred 3D maps while 47%

preferred 2D maps. In summary, while various way finding and navigational strategies have different purposes, the map's efficiency in navigating does not significantly differ from that of other navigational techniques (3D/AR).

QR Code

QR (Quick Response) codes, a 2D symbol, were invented in 1994 by Denso Wave, a member of the Toyota group of companies. Originally intended for production control, they have since found widespread use in various fields. It typically appears as a small white square that has a black geometric shape and can hold details such as URL, phone number, SMS message, and any text that is better than a regular bar code (Ashford, n.d.). Its practical and engaging way of representing data has made it a global trend in recent years. According to the article of Hayes (2021), QR codes can be classified into six types. Micro QR Codes are smaller versions of traditional QR codes, designed for constrained spaces, starting at 11 x 11 modules and capable of encoding up to 21 alphanumeric characters. Model 1 QR Codes, the precursor to Model 2 and Micro QR, range from versions one to 14 within the AIMI standard. They hold a maximum data capacity of 468 bytes, encoding up to 707 alphanumeric characters. Model 2 QR Codes, an advancement from Model 1, offer improved alignment patterns for better position adjustment and higher data density. These codes range from versions one to 40, with version 40 accommodating up to 4,296 alphanumeric characters. QR codes come in various square or rectangular formats to accommodate space or shape limitations, with a total of 61 formats available. SQRC is designed with restricted reading functions to safeguard private information. Frame QR allows customization, accommodating larger data and formats like graphics, illustrations, or photos.

In a study by Rodriguez, Chaudhari, and More (2016), it was noted that one-time passwords (OTPs) are more vulnerable to risks like phishing and spoofing, unlike QR codes, which offer greater convenience.

Today, QR codes are extensively utilized in Japan for several reasons (Soon, n.d.) such as the diffusion of QR codes throughout Japan and East Asia. This is a leading example of how a square matrix and machine-readable data can exceed their projected use and develop as a significant component of informational infrastructures (de Seta, 2023). Additionally, QR codes serve as the bridge between the physical world and the digital world, and they are also used in museums or other cultural institutions to quickly connect the data from offline to online content and receive all the designed data (Marwan et al., 2020). In the current era, smartphones are ubiquitous, with most individuals owning one, especially smartphones equipped with cameras ideal for QR code applications (Ruan & Jeong, 2012). Given their extensive use across diverse fields, QR codes can be regarded as valuable markers. The proposed application may further extend its functionality to various areas with the use of QR codes.

A* Algorithm

The A* Algorithm is a popular search method for path planning in mobile navigation systems. Its primary purpose is identifying the best route or path from the starting point to the goal node (Ravikira, 2023). The algorithm uses heuristic knowledge as one of its components, which is an estimation of the distance between the target node and the current node, to prioritize nodes that are closer to the goal node. It also incorporates a cost function to keep track of the cost of reaching a specific node from the starting node. To avoid revisiting nodes, the algorithm uses open and closed sets to identify discovered and undiscovered nodes (Karur et al., 2021) which are the other two components of the algorithm.

The A* algorithm was known for its speed and was considered as one of the most powerful tools for finding the shortest path (Wang et al., 2021). While it may have certain limitations, such as slower performance due to right-angle turns, it remains to be a valuable and helpful algorithm (Wang et al., 2021).

When compared to other search algorithms, using the A* algorithm in a Digital Museum Navigation System offers several advantages. These advantages include (a) a comprehensive algorithm; the A* algorithm can find the lowest cost for a problem and explore all possible outcomes. (b) Wide range of applications; the algorithm has diverse applications in areas such as robotics, route planning, logistics, and video games (Ravikiran, 2023). (c) Improved system performance; researchers have already used the A* Algorithm and made improvements, leading to enhanced system performance (Li et al., 2015).

To implement the A* algorithm in a Smart Navigation System, the museum map will be divided into nodes that represent specific locations. By using the components mentioned above, such as heuristic knowledge, cost function, and open and closed sets, the A* algorithm can successfully find the shortest path between two points in the navigation system (Wang et al., 2022).

Application of A Algorithm in Finding Navigational Paths*

In the field of pathfinding research, the A* search algorithm have been employed for a long time. It is frequently cited to have advantages over other tools because of its effectiveness, simplicity, and modularity. A* has emerged as a popular choice for researchers aiming to address pathfinding problems as a result of its accessibility and extensive use. A study by Foead et al., (2021) provides a systematic literature review of A* pathfinding, wherein they conducted a 29 node, 4 intersection experiment placing A*, HPA*, IDA*, and Dijkstra algorithms against each other. The researchers have found that efficiency is the crucial factor of A* search. While the majority of well-designed pathfinding algorithms can locate the solution, many of them will require more time, resources, or both than A*. In terms of overall efficiency, there is a difference of up to 40% and nearly 30%.

In addition, A* is especially flexible and may be modified to meet a variety of requirements as needed. However, not all improvements are necessarily better, and some alterations that favor speed might not ultimately discover the optimal path. This was evident from the results of their experiment, as HPA* was unable to determine the fastest path despite finishing quite quickly, whereas the other algorithms took longer but still produced the best results. While desired, finding the most optimal path is not always required, depending on the application (Foead et al., 2021).

Another study by Sunjana (2021) used Visual Basic programming language to simulate and figure out how A* algorithm works and is applied as a solution for finding the optimal path, in the condition of a normally congested road. The researcher carried out the test using path counting, also known as step calculation, on three different case samples, each having a 25 x 25 sized case representation in array form. From the results of the analysis and testing done on the A* algorithm, the researcher concluded that (a) the A* algorithm may be applied to numerous problems such as finding the path to take. (b) With the obstacles provided for each path, the test can find the optimal path. In accordance with the test results, the discovered path has the lowest value in comparison to other paths, making it the optimal path. (c) Lastly, for further research, the effectiveness of the A* algorithm should be compared to other algorithms that are claimed to be more effective in selecting the optimal path.

Overall, the current pathfinding problems have become too demanding for A* algorithm. Other algorithms can deliver the same performance while requiring less overhead, and as grid size increases, the issue only gets worse. However, when working with large maps, A* algorithm may reach exceptionally quick times with high accuracy while only having somewhat greater overhead costs due to the incorporation of innovative modifications like various heuristics types or supplementary components to the algorithm. While the traditional A* algorithm is showing its age, improved algorithms derived from it are more than capable of meeting current pathfinding demands. HPA* and other derivative A* search algorithms are used to overcome the constraints of A*. Depending on the problem, HPA* can compete with and even outperform other similar algorithms (Foead et al., 2021).

Adoption of 2D Mapping in Indoor Navigation

The need or demand for spatial information regarding large indoor spaces is growing along with the number of individuals living in cities. This includes detailed indoor models and maps that can be utilized for a variety of purposes, such as route planning and navigation assistance. As stated by Man et al., (2016), public spaces like malls, airports, museums, and concert halls have grown bigger and more complex as a result of rising urbanization. Thus, even if someone is familiar with the area, it becomes challenging for the individual to get to a particular room or location. So, while there is relatively not much utilization of 3D indoor models, 2D maps are frequently used to enhance positioning and increase accuracy. Because 3D techniques are primarily intended for simultaneous mapping and localization (Kourosh & Sisi, 2016).

Because of the complexities of interior spatial systems and the absence of global references, mapping an indoor survey is a difficult task (Zlatanova et al., 2013). The interior area is dispersed across a three-dimensional space and consists of variously shaped and functional rooms, hallways, stairwells, and other structures. One of the features of public buildings, such as those seen in hospitals, supermarkets, and airports, is that the indoor environment can have a very large spatial expanse. Human activity in these environments makes it challenging to acquire mapping results since moving items require robust outlier identification, and interior environment layouts are subject to regular changes (Chen et al., 2018).

Conventional Global Navigation Satellite System (GNSS)-based or Inertial Navigation System (INS)-based mobile mapping techniques may not be used inside because Radio Frequency (RF) signal blockage prevents the use of GNSS signals to determine absolute locations. Although stationary total-station-based surveying and mapping may produce reliable indoor mapping results, it is a tedious interactive approach with inefficiency for extensive indoor mapping and updating. The research community has demonstrated that Simultaneous Location and Mapping (SLAM) is a viable method for indoor mapping. It often used photographic sensors such as cameras, range sensors such as radar, LiDAR or depth cameras such as the Microsoft Kinect (Zhang et al., 2014). It can be classified as visual SLAM, LiDAR SLAM, or RGBD SLAM, the three most popular SLAM approaches, depending on the sensors utilized (Chen et al., 2018).

Development of a Smart Directory Application Using the A* Algorithm

A* algorithm has been used in many pathfinding systems, like indoor navigation and routing systems. In a paper and project developed by Kasim et al. (2017), they used the A* algorithm to find the most optimal path in navigating the school's Faculty of Computer Science and Information Technology (FSKTM), aided by an intuitive and user-friendly design. A similar project was also created by Gorovyi et al. (2017) but they employed sophisticated methods to put the A* algorithm to work. They harness the potential of Bluetooth beacons to establish real-time indoor user localization and construct a graph-based path where both Dijkstra and A* were used to find the shortest path from one node to the other. Though they have a similar purpose of finding the shortest path, the two algorithms have different approaches. Dijkstra is a greedy algorithm that explores every path to the goal before finding the optimal path, while A* uses heuristics to probabilistically estimate the optimal path without actually exploring the whole graph. It makes the A* more efficient in dealing with larger search spaces compared to Dijkstra which goes slower with increasing size (Rachmawati & Gustin, 2019).

Potential Advantages and Disadvantages of Using 2D Mapping in an Application

In an article written by Rachael (2023), the difference between 3D and 2D maps was explored. Among these, the advantages and disadvantages of 2D maps are extracted. Two-dimensional (2D) mapping is a simplified method for presenting spatial data, using X and Y axes to showcase width and height. It's effective for communicating information through conventional visual methods like graphs and charts, making it straightforward to create and understand. However, 2D mapping might not fully capture the intricacies of spatial relationships and depth, potentially oversimplifying data. Although suitable for simpler datasets and general audiences, it lacks the ability to represent depth and may necessitate multiple maps to showcase different aspects of the data, leading to fragmented interpretations and reduced accuracy in illustrating spatial complexities.

Moreover, the study of Savage (2010) highlighted that 2D maps excel in simpler tasks that do not involve elevation data, showing better precision and effectiveness compared to 3D maps. Yet, for tasks related to elevation information or integrative elements that do not specifically require elevation details, there was not a significant advantage seen with 3D maps. The participants' prior experience did not notably influence their performance with 3D maps, likely due to their familiarity with 2D topographic maps. Essentially, the study emphasizes that 2D maps are advantageous in handling simpler tasks, while 3D maps might offer a more comprehensive understanding in complex tasks that involve elevation data.

Potential Advantages and Disadvantages of Using QR Code in an Application

QR codes have the advantage of incorporating tracking elements, which enable businesses to collect analytical data about user behavior, scan frequencies, and geographic locations. This information aids in refining and enhancing marketing strategies. Also, QR codes offer a cost-effective marketing approach for businesses. By facilitating direct communication with customers, these codes allow for promotions, offers, or product details, thereby reducing the expenses associated with printed marketing materials (Supercode, n.d.).

Additionally, the seamless and interactive functionality of QR codes not only enriches the user experience but also ensures a more convenient and engaging way for users to access information. This functionality leads to smoother interaction and engagement when connecting with content, further enhancing the user experience (Go, 2021).

With the advantages presented, QR codes also come with certain inconveniences. To effectively use these codes, a smartphone with a scanning feature is needed. Although some newer smartphones have this functionality integrated into their camera apps, many users might have to download a separate QR code scanner. There are also individuals who use non-smartphones or might not have immediate access to their mobile devices. Additionally, to access the content linked to the QR code, an internet connection is required. However, individuals facing low signal strength or lacking Wi-Fi access might be unable to reach the content embedded within the QR code (Image Works, n.d.).

Potential Advantages and Disadvantages of Using A* Algorithm in Pathfinding

A research conducted by Foead et al., (2021) using a literature review focuses on using A* search in pathfinding and search algorithms, wherein it covers 40 papers. The researchers used several studies as a guide to discuss the potential advantage and disadvantages of A* in different scenarios. Its advantages and disadvantages are the following:

Potential Advantages

- Utilizes heuristic functions to reach its target
- Find a path much quicker than uninformed search
- There is up to a difference of over 40% when it comes to efficiency in general and close to 30%

Potential Disadvantages

- Does not guarantee that the shortest path will be the outcome. According to studies, the A* algorithm will only provide a solution where it finds the shortest path 85% of the time in a few scenarios involving strategy maps and mazes.
- Poor outcome when it comes to large maps

Developmental Tools

Under this topic is the list of all developmental tools used in the research. The tools discussed are the development environment (Android Studio, Godot 4, and Unity), and programming language (C# and GDScript). These tools are necessary for the design and development of the proposed smart campus navigation system.

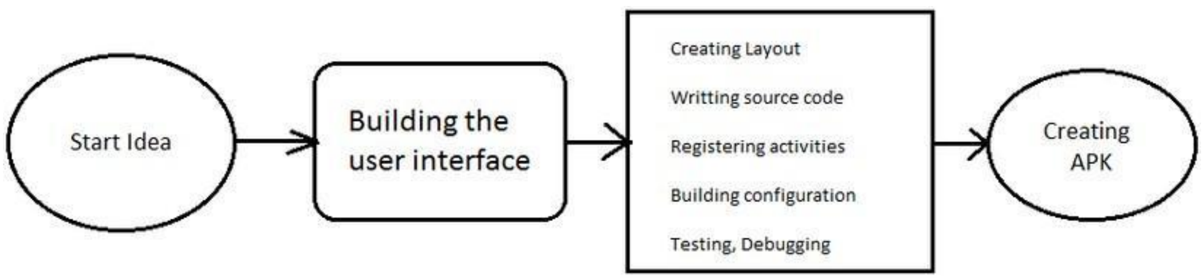
Development Environment: Android Studio

A Linux-based, open-source operating system for smartphones called Android was developed by Google and allows third-party developers to create applications for Android and Linux devices. The daily Android operating system has grown in popularity in the electronics industry, particularly in the mobile phone sector (Kocakoyun, 2017; Sisodia, 2022). Due to free access to several developmental tools, it has served as an invaluable source of inspiration to using the Android system and is frequently used by researchers. Additionally, it enables developers to conveniently execute their ideas by utilizing such a suitable hardware platform (Kocakoyun, 2017).

Android Studio is one of the known open-source software and the official Google integrated development environment (IDE) for Android development. This software is more cost-effective and offers a variety of application development tools on all Android devices. The key benefit of this is the emulator tool which is a real-time platform used to test the created application on. Furthermore, using USB debugging, the application may be tested on mobile phones (Megalingam et al., 2019). The diagram in Figure 1 (MIHAIL-VADUVA, 2018, p. 37) shows the process of application development using Android Studio.

Figure 1

The Process of Development of an Application Using Android Studio



Note. From *Enriching Curricula with Mobile Solutions*, by D. MIHAIL-VADUVA, 2018.

Development Environment: Godot 4

First conceptualized in 2007 but officially released in 2014, the Godot game engine is a free, open-source and cross-platform game engine specialized in both 2D and 3D game development. Its name came from Samuel Beckett's famous play, Waiting for Godot (Dealessandri, 2020). In the latest charts of Itch.io, a top website for downloadable indie games and game development resources, Godot is in the top four of most preferred game engines, topping Unreal Game Engine.

Though Godot supports 3D game development, it currently excels in 2D development. Godot offers a wide range of resources for development, which encompasses an integrated code editor, a graphics rendering engine, tools for audio playback, animation capabilities, and other features. Aside from these, it also has a dedicated scripting programming language, GDScript, that bears similarity to Python. Despite this, it still supports other scripting languages, like C# and C++, through specialized packages (Zenva, 2023).

Furthermore, Godot offers an extensive library of pre-built nodes that cover a wide range of functionalities necessary for any game. These nodes include graphics, sounds, user interfaces, cameras, animations, characters, and many others. By using these pre-built nodes, the tedious task of coding basic classes for the game from scratch can be avoided. The built-in nodes in Godot are already equipped with the necessary functionality, saving time and effort. Additionally, if there is a desire to add further customization, there is an option to enhance these nodes using custom attachable scripts (Harman, 2021).

Programming Language: GDScript

GDScript serves as the tailored scripting language exclusively designed for the Godot game engine. Its high-level nature prioritizes readability and ease of use, especially when compared to lower-level counterparts like C++. GDScript's core purpose revolves around game development, incorporating features that expedite and simplify the creation process (Zenva, 2023).

Although there exist other alternatives, most users still prefer GDScript since it is seamlessly integrated with the game engine itself. It is also accessible for all types of people who want to jump into scripting, regardless of experience, since it is intuitive and easy to learn. Finally, it is also optimized for game development, providing a smooth development process for all needs (Chickensoft, 2023).

2D Development: Unity Game Engine

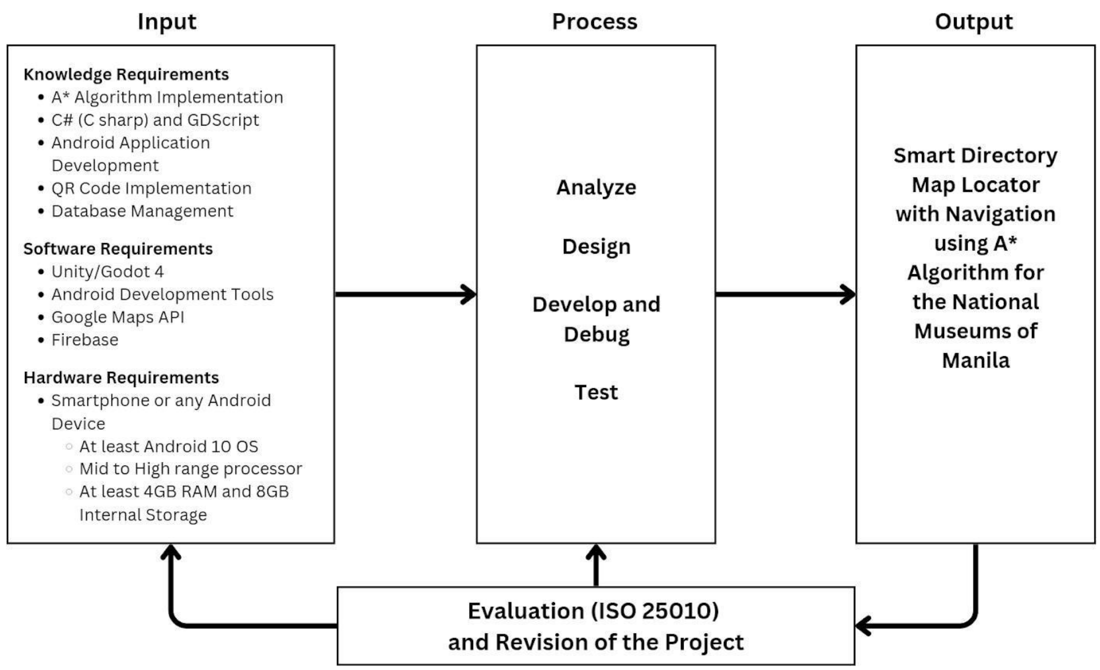
Unity, released in 2005 and developed by Unity Technologies, is a 2D and 3D cross-platform game engine that aims to grant more developers access to game development tools. Throughout its extensive lifespan, the engine has undergone significant transformations and expansions, adeptly adapting to the latest practices and technologies. It remains dedicated to offering the most comprehensive set of tools for the game development industry while prioritizing user-friendliness for developers of all skill levels, including beginners. Furthermore, Unity has successfully extended its influence to other industries, placing significant emphasis on real-time 3D development and positioning itself as one of the most potent engines available (Zenva, 2023c).

Among the vast range of tools (animation, audio, scripting APIs, large asset store, etc.) that can be used and the creations that can be built with Unity, the researchers will use its capability of employing 2D systems using various packages that can be integrated with the game engine.

CONCEPTUAL MODEL OF THE STUDY

Figure 2

Conceptual Model of the Study Using the Input-Process-Output (1PO) Model



Input

The conceptual model's input component includes knowledge needs and software requirements. Understanding the A* algorithm implementation, which is a popular search method for path planning, and familiarity with the GDScript and C# (Cs sharp) programming/scripting languages, which will be employed to code the system, are knowledge requirements. Additionally, knowing about the Android application development process, how to deal with QR codes, and database management are also necessary to have a solid foundation of how the software will come to fruition. Unity and Godot 4 game engines are the primary development environments for creating the application, and with the help of Android Studio as the publisher, which are the software requirements. For the hardware requirements, a smartphone or any Android device is required for the system to work, with at least Android 10 operating system, mid-range processor, 4 GB RAM, and 8 GB internal storage.

Process

The process block includes analyzing, designing, constructing/debugging, and testing activities to develop the system as well as the mobile application for the Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Manila.

Analyze. During this stage, the museum navigation application requirements will be acquired and evaluated in order to identify the system's functions and features.

Design. The design step involves creating a complete strategy and structure for the system, which includes the creation of the user interface, database, and integration of the A* algorithm and QR code.

Develop & Debug. The actual coding and execution of the system will take place throughout the development and debugging stages. Also, any issues or flaws will be identified and managed.

Test. Finally, the system will be thoroughly assessed through the testing step to ensure its efficiency, accessibility, and performance.

Output

The output component of the conceptual model is the development of the Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Manila. This output includes a fully operational and user-friendly mobile application that aids staff and visitors in navigating and assisting them in exploring the national museums.

Evaluation and Revision

The system will be evaluated and revised using ISO 25010 as a standard.

OPERATIONAL DEFINITION OF TERMS

The following terminologies are defined for a better understanding of the study:

- **A* Algorithm** refers to a popular search algorithm used for path-finding and navigation systems.
- **Mobile Application** is designed to run on mobile platforms like smartphones or tablets.
- **Navigation System** is a tool that helps users choose the best path to take to reach their destination.
- **Optimal Path** is the most efficient or quickest path between two specified locations.

CHAPTER III

METHODOLOGY

This chapter includes the project design, development procedures, system operations, testing processes, and evaluation procedure of the system.

Project Design

Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Manila are important not only for the researchers but also for those who want to enjoy the trip to the museums with ease. The mobile application lets the user select the museum of their choice, the artist and artworks of their choice, and view the progress of their visited galleries.

When the user has already chosen a specific museum, artwork, or artist, the application will display or give the most optimal route to a certain destination that the user has chosen. The user still has the freedom to change their destination anytime and the user's progress will not be compromised.

The user's visitation progress is stored in their user profile, which can be accessed through the profile info tab. Moreover, administrators have their own platform to access this information, allowing them to effortlessly manage the system's progress as well as update necessary details on the museums for application management and maintenance. Users may continue their journey anytime and track the galleries they already visited so the users can visit other places in the museum next time. The users may also access the gallery which users can use to identify the artworks they want to view and visit, giving them options to search the destination of a certain artwork, sculpture, artifact, gallery, and artist.

Flowchart Diagram

The system flow is shown in Figure 3. In the diagram, the logical sequence and flow of the system is visually represented through flowchart symbols. The users should create a new account or log in if they already have an existing account to access the homepage and see the introductory information about the application. After logging in, the user may access their profile or pick a museum so the application can give the most optimal route to the chosen place.

Figure 3

System Flow

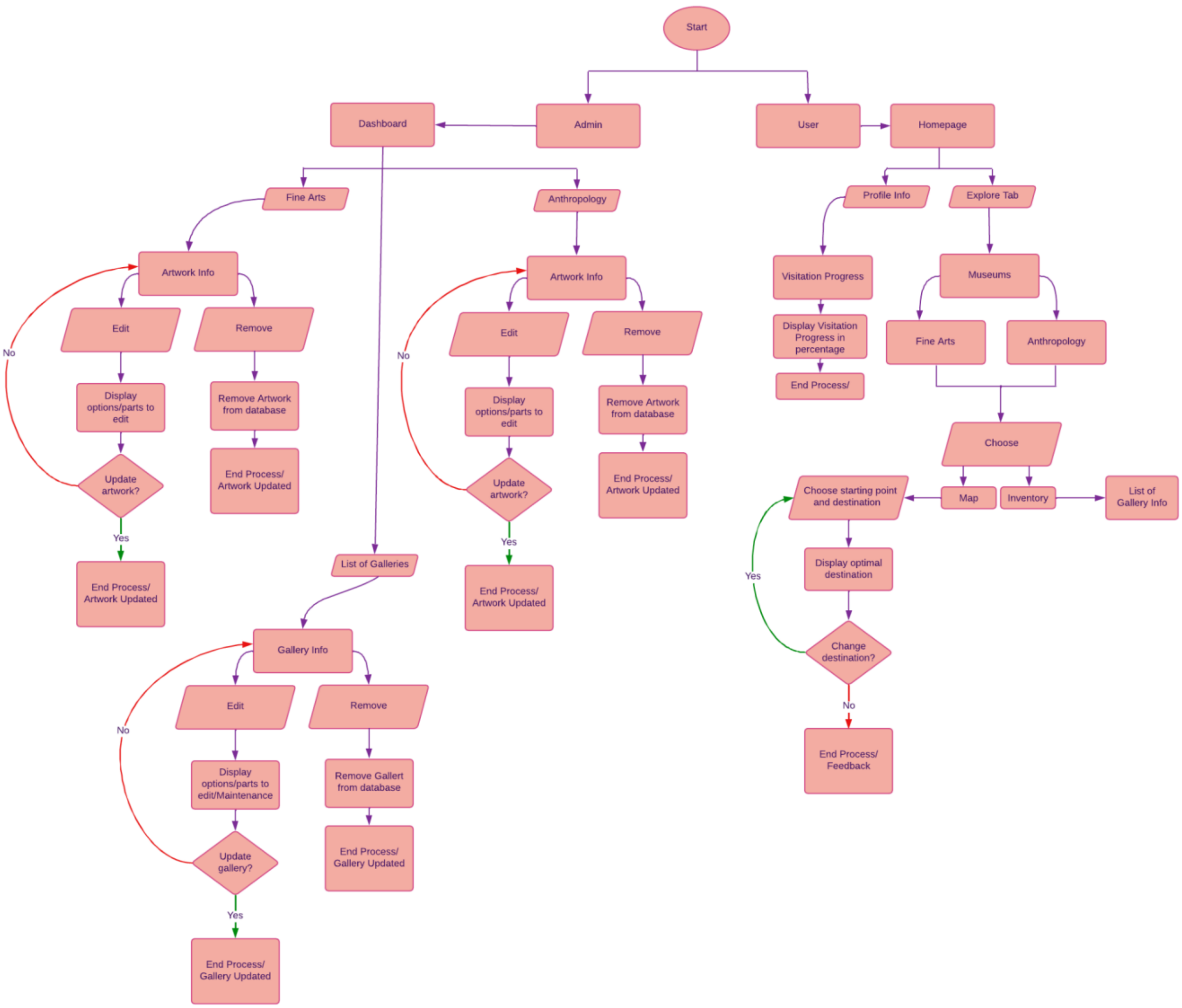


Figure 4

Program Flowchart of Artificial Intelligence

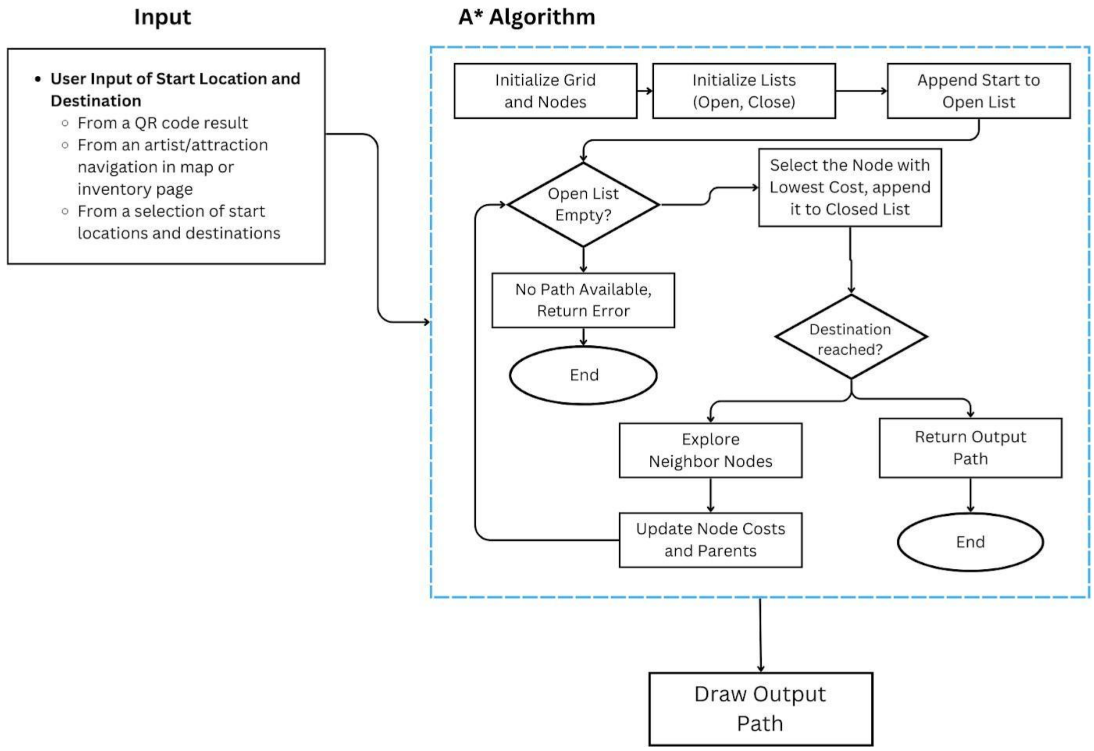


Figure 5

Context Level Data Flow Diagram Lvl 0

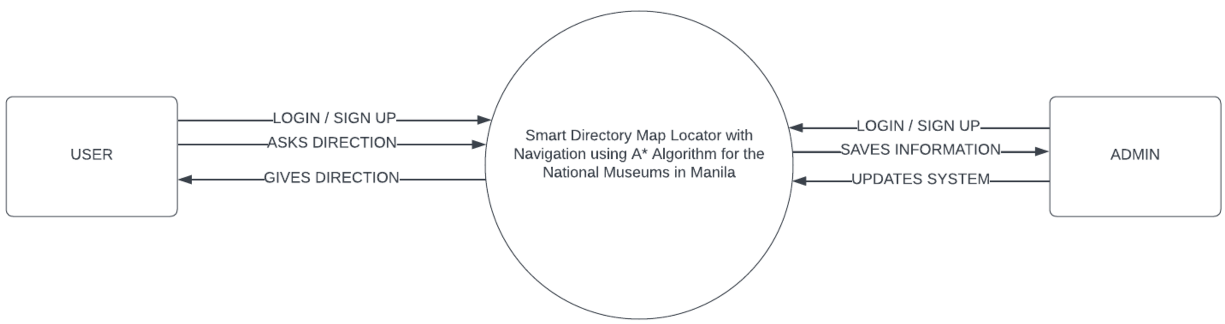
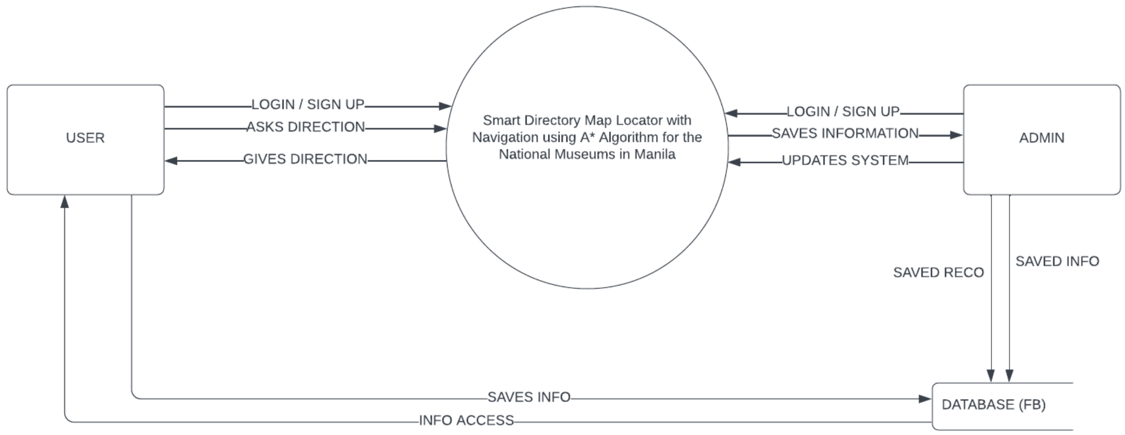


Figure 6

Context Level Data Flow Diagram Lvl 1



In Figures 5 & 6, the context-level data flow diagram level 0 and 1 illustrates the accessible features of the system using the application. The application comprises a Homepage, Profile Info, and tabs for the two museums in Manila. The primary system feature is to locate the user's destination and provide directions with the shortest path. Admins may save information and update the system.

Figure 7

Entity Relationship Diagram for Log-In and User Data

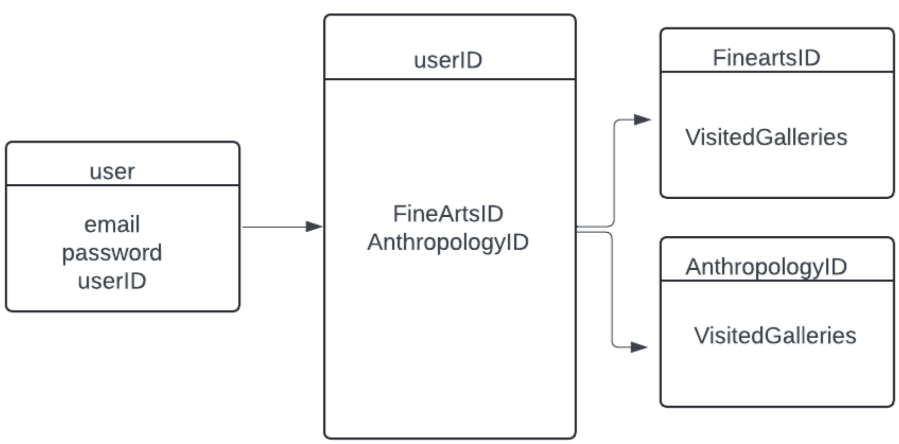


Figure 8

Entity Relationship Diagram for Admin

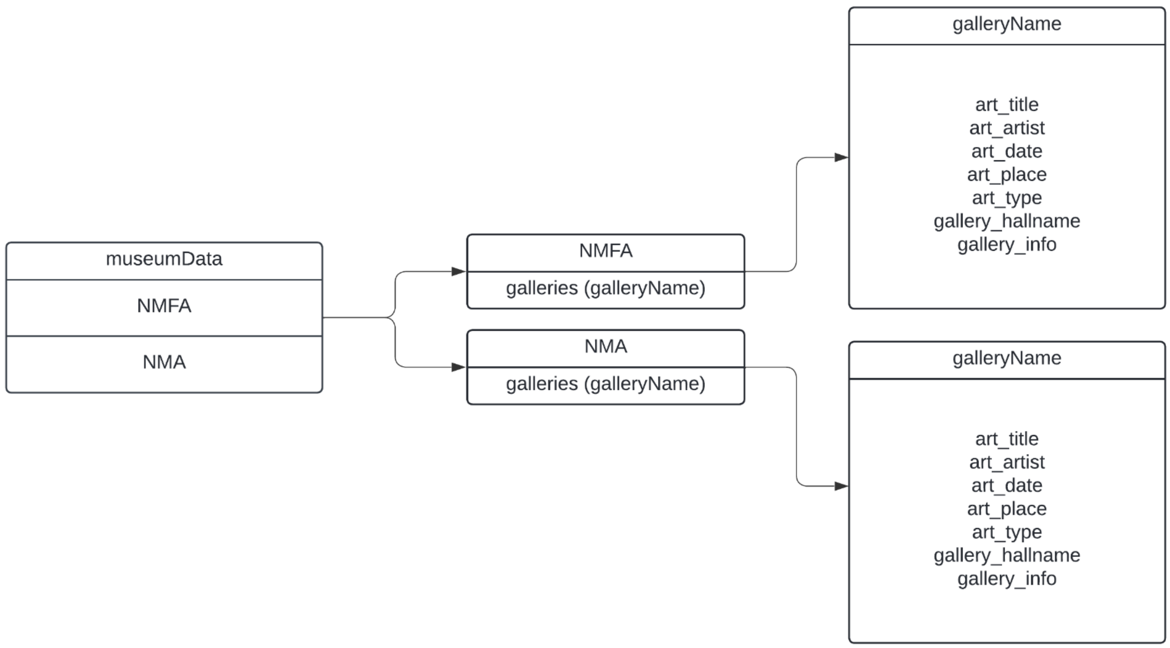
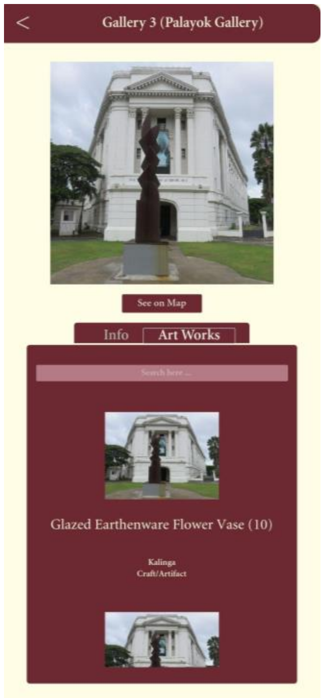


Figure 9

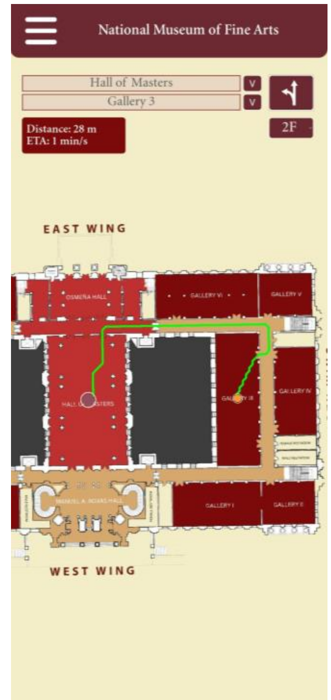
Wireframe

GALLERY ARTWORK PAGE



INVENTORY PAGE

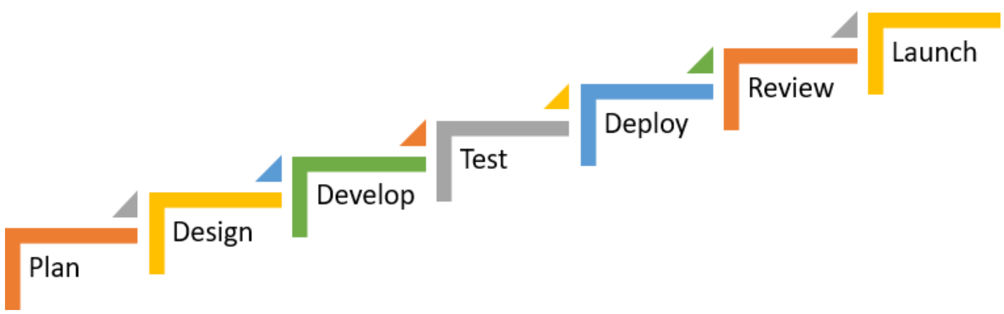
MAP NAVIGATION



PROJECT DEVELOPMENT

Figure 10

Agile Software Development



This section of Chapter 3 outlines the development process of the project and provides an overview of the procedures that follow the project's specifications. The researchers have chosen to utilize the Agile Software Development method to create the system.

Agile Software Development has distinct phases that provide a more structured guide for the development of the application. It has seven key phases, namely: plan, design, develop, test, deploy, review, and launch.

Plan. The research team will initiate a brainstorming session to outline the study's requirements thoroughly.

Design. In this phase, the researchers will focus on developing the user interface (UI) of the system. Designing the UI will be the primary objective, aligning it with the study's specifications

Develop. Actual coding takes place in this phase, and the application is produced according to accepted specifications. Researchers are responsible for addressing and fixing potential issues, making this phase pivotal to the entire project.

Test. During this phase, the researchers will rigorously test the programme to ensure the system is entirely error-free.

Deploy. Clients gain access to the application for beta testing. Users receive instructions on proper usage and provide initial feedback during this phase.

Review. A comprehensive review is conducted to assess the application's performance. Any concerns or problems are addressed to ensure the project objectives are met.

Launch. The final phase involves the official launch of the application for widespread use.

OPERATION AND TESTING PROCEDURE

The system should be free from any bugs or errors that might affect the user's experience or possibly break the software. Software testing will be done to make sure there are no issues with the system that might affect how well users interact with it or its functionality.

1. The system is accessible on any Android mobile devices and an internet connection is needed to load the mobile application.

2. Registration of an account is needed to login and access the *Homepage*.
3. Once the user has logged in, the screen redirects to the *Homepage*, where the features of the system are displayed, wherein it provides introductory information about the application and lets the user choose between accessing the *Profile Info* tab or the *Explore* tab.
4. In the *Explore* tab, the user may select one of the two national museums (Fine Arts and Anthropology) they want to visit.
5. After selecting a museum, press the map button then the user will redirect to the museum's map where the user may input or choose themselves which artist, art, artifact, sculpture or gallery they would like to visit.
6. Once the user selects their desired destination, the system will display the optimal path to their choice of destination. User may tap the gallery on the map to view the info panel of that gallery, where they can also choose and redirect to the gallery info page to view more information about it. If the user has a change of mind and wants to visit a different location, the system also allows them to change their destination thereby redirecting them back to the map where they can input or select what they now want to visit.
7. In the *User Profile Info* tab, the profile of the user is shown along with their username. The tab also allows users to view their museum visitation progress and the list of galleries they have already visited.
8. Users may also access the Inventory by selecting the search button in the *Explore* tab or choose *Inventory* in the menu found on top of the map, beside the name of the museum. Here, users can select among the floors and galleries found in the specific museum. They may also view and recommend to other users the artworks, sculptures, and artifacts displayed in a certain gallery at the

bottom of the screen.

9. Administrators have to log-in on the museum admin website to access information on the application. By going to the dashboard, they may choose to view the Fine Arts tab, Anthropology tab, or the List of Galleries tab. The Fine Arts and Anthropology tabs allows admins to see, edit, save, and delete information of specific artwork. Meanwhile, in the List of Galleries tab, they can view the list of galleries in the museums and check their information. Likewise, they may also edit, save, and delete information and update the status of a gallery.

The system will be tested using the testing procedure described in Appendix A, which involves creating a list of test cases that detailed the actions that needed to be executed for each system function and the expected output once all the steps are completed. The desired output from each system function is displayed alongside the actual output to determine if the expected output is obtained.

Evaluation Procedure

In order to evaluate the developed system, the ISO 25010 software quality metrics will be used to determine the system quality. The respondents consist of 40 Information Technology (IT) and Computer Science (CS) students, 10 Information Technology (IT) and Computer Science (CS) professionals including faculty members and professionals from the industry, and 20 museum visitors, resulting in a total of 70 respondents. They must be proficient in mobile application development, wayfinding, and 2D mapping or have experience conducting research. They will assess the system using Appendix B, which lists the relevant factors that should be considered for the system. The following procedure is used as a guide to evaluate the overall quality of the developed system:

1. Invite respondents who are familiar with mobile application development,

wayfinding algorithms, and 2D mapping. IT and CS students and professionals and museum visitors will serve as the system's evaluator-respondents.

2. Provide a live system demonstration to respondents in person or an online demonstration for online respondents in case they require further details and experience using the system.
3. Following the system demonstration, the evaluator-respondents are requested to evaluate the system using a form that was based from ISO 25010, taking into account their observations and experiences.
4. After processing the completed evaluation forms, the data is tabulated in Microsoft Excel to calculate the mean ratings.
5. The 4-point Likert scale presented in Table 1 is used to analyze the adjectival ratings for the mean ratings.

Table 1

4-Point Likert scale

Scale	Adjectival Rating	Range
4	Highly Acceptable	3.4 - 4.0
3	Very Acceptable	2.6 - 3.3
2	Acceptable	1.8 - 2.5
1	Not Acceptable	1.0 - 1.7

The 4-point Likert scale is shown in Table 1 containing the scale, adjectival ratings, and range for each rating. The Likert scale was employed in the system evaluation to measure the system based on several criteria, including usability, performance efficiency, and functional suitability.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the results and discussion of the conducted study, it also includes the project description, project structure, and project capabilities and limitations, as well as the project test result and evaluation.

Project Description

The researchers developed a smart navigation mobile application for the National Museums of Manila, which provides a quick and easy way to navigate around large structures around the National Museums of Manila. Making it easier for them to explore and easily find certain sculptures, paintings, artifacts, etc. by optimizing the shortest path by using A* Algorithm. The mobile application is intended to be beneficial to students, researchers, National Museum staff, and tourists around the world. Access to the internet is necessary to operate the mobile application. It was developed using Godot, which develops systems for desktop, mobile, and the web.

The smart navigation mobile application presents various interfaces for different modules such as Sign-in/Sign-up, Gallery, Visitation Progress, and Shortest Path. Modules for Sign-in/Sign-Up are accessible even without logging in on the mobile app. While Profile, Gallery, Visitation Progress, and Shortest Path modules are only accessible once the user logged in. Users can create accounts and log in on the Sign-in/Sign-up module. Profile module gives personal information that the user has provided such as username, as well as the user’s visitation progress in the National Museums. Gallery module displays the necessary information about the paintings, artifacts, sculptures, etc. which includes a short description, artist, type of art/sculpture/artifact which allows users to view different galleries every floor from different museums. Visitation Progress tracks the user’s progress depending on the number of galleries visited. It is displayed in percentage and the user can revisit their progress to identify the galleries that are not yet visited by the user. Lastly, the Shortest Path module helps users find the easiest/shortest path to their chosen gallery. This module uses A* Algorithm and automatically displays green highlighted path to guide users to their path once they have chosen their point of destination. Other information, i.e. the estimated time of arrival (ETA) and distance of the path, are also automatically displayed on the screen.

Project Structure

Login Page

This is the entry point at which the user registers and logs in, in order to use the application. Additionally, this is the section where users attempting to use the program are required to provide their email address and password. Admins will be able to login using their admin account and entering the admin passcode.

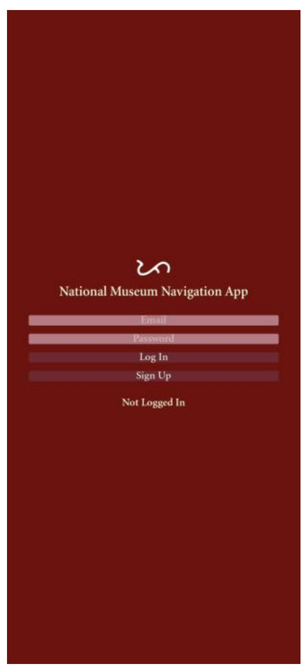


Figure 11. Login Page.

Homepage

The home page is where the username appears; there is a profile info tab and an explore tab that will lead the user to a specific part of the system. The profile info tab shows the visitation progress of the user, and the explore tab shows the two museums that the user can explore and navigate using our application.

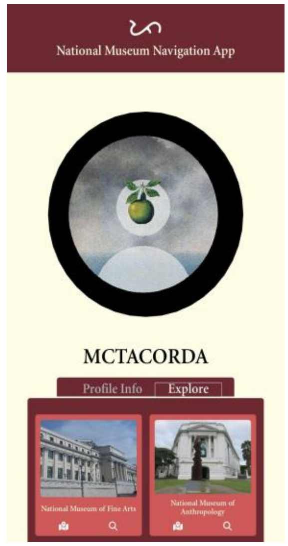


Figure 12. Homepage.

Menu and Gallery Info Panel

This part of the system shows the map of the selected museum, highlights the selected gallery of the user, displays the artwork's information in the gallery info panel, and shows more information, including the artist, type, and date, by clicking the See Info button.

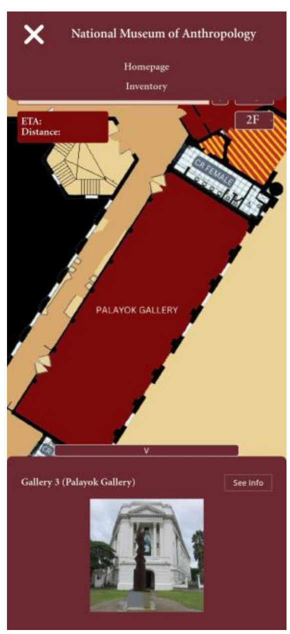


Figure 13. Menu and Gallery Info Panel.

National Museum of Anthropology (left) & National Museum of Fine Arts' (right)

Artwork Page

This part of the system shows the artwork's information, including the place, artist, type, and date. It also has a search bar that users can use to find specific artwork that they wish to see.

Figure 14. National Museum of Anthropology (left) and National Museum of Fine Arts Artwork Pages.

National Museum of Anthropology (left) & National Museum of Fine Arts' (right) Gallery Info Page

This part of the system shows the gallery's information.

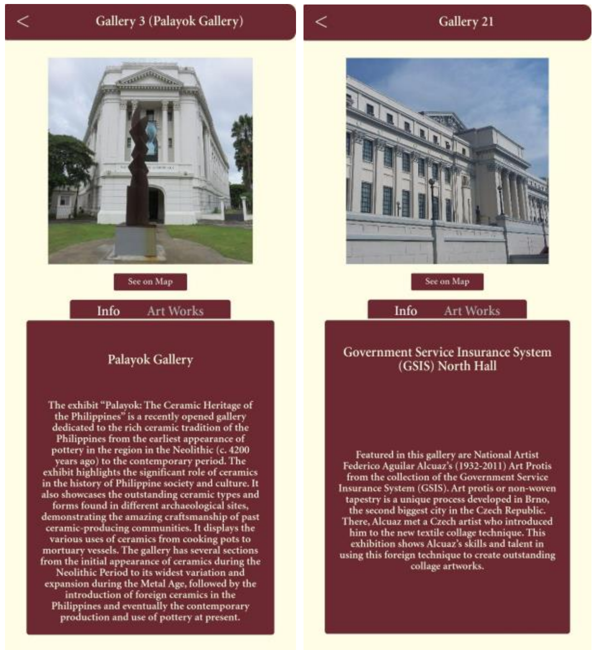


Figure 15. National Museum of Anthropology (left) and National Museum of Fine Arts (right) Gallery Info Pages.

National Museum of Anthropology (left) & National Museum of Fine Arts' (right) Inventory

This is where the specific floor's information and artwork were shown. Arrow buttons can be used to move from one floor to another.

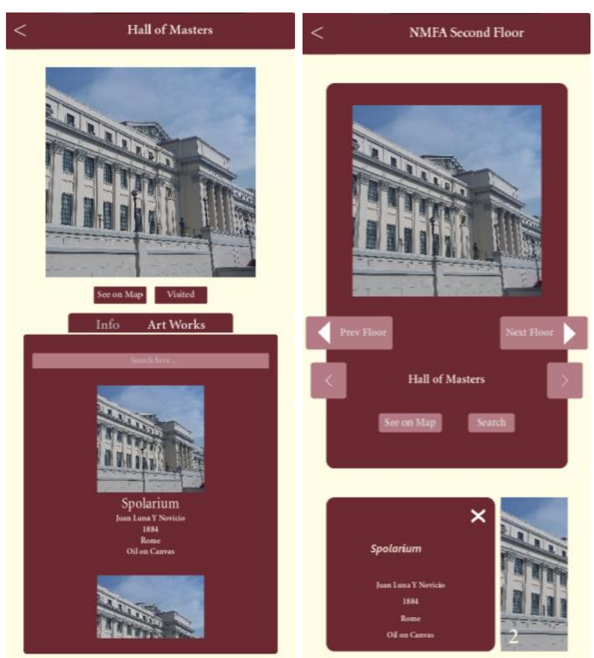


Figure 16. National Museum of Fine Arts Inventory.

National Museum of Anthropology (left) & National Museum of Fine Arts' (right) Map Navigation

This page shows the museum's floor plan, which displays a bright green path line when used in navigation. From the search boxes above, users can select their beginning and ending points. The distance between the starting and ending points, as well as the anticipated time of arrival, are also displayed. Besides the search bars, there is a display indicating what floor the user was on.

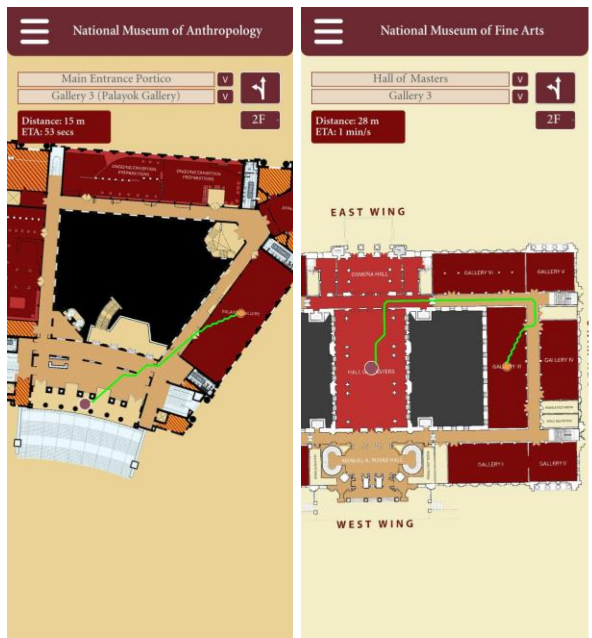


Figure 17. Navigation.

Admin Account Access in the Application

Admins have an admin account to access, manage, and update information displayed in the application. Once the admin has logged in, they are immediately redirected to the page with the Profile Info and Maintenance tabs. In the Profile Info tab, they can change the admin passcode as well as view the users and their visitation progress. Meanwhile, in the Maintenance tab, they can choose between the Anthropology or the Fine Arts tabs to view, add, edit, and remove from the list of artwork information for the artworks, artifacts, and sculptures exhibited at that specific museum.

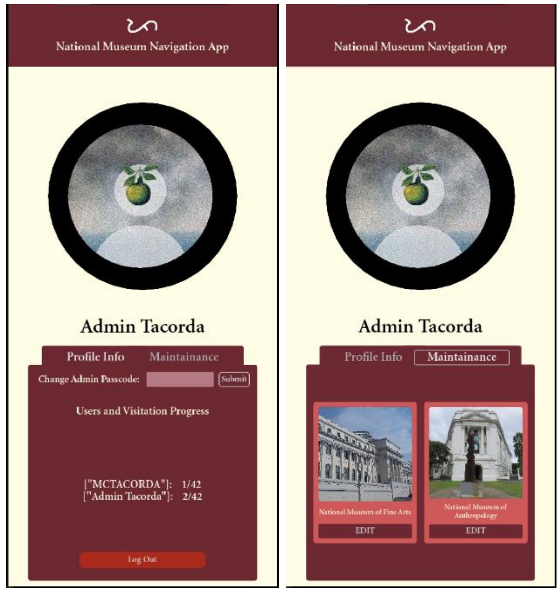


Figure 18. The Profile Info (left) and Maintenance (right) tabs after logging into the admin account.

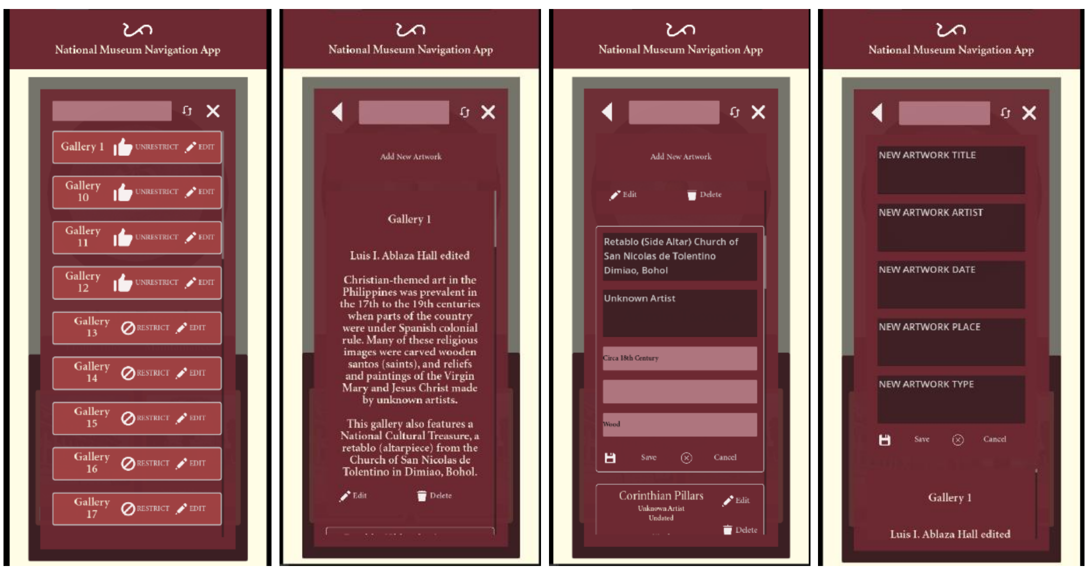


Figure 19. The gallery list with Restrict and Edit buttons (first), edit a specific gallery page (second), edit a specific artwork page (third), and add a new artwork page (last) in the admin account.

Project Capabilities and Limitations

The following are the capabilities of the system:

1. The mobile application can provide an accurate route or path that guides the user through navigation inside the premises.
2. The mobile application can provide information about the artworks that were being

displayed in the museum.

3. The mobile application displays the shortest path, ETA, and distance from one place to another.

The following are the limitations of the system:

1. The mobile application can only navigate and display a path or route inside the specific museum that the user has chosen.
2. The mobile application can only be accessed on Android devices.
3. The mobile application can only be used as a navigation tool in the national museums located in Manila, specifically in Anthropology and Fine Arts.

Test Results

The tables below show the testing procedure for each module containing the steps undertaken during testing and the actual results. The actual results of the testing were compared to the expected results from Appendix A.

Table 2

User Registration Module Test Result

Steps Undertaken	Actual Result
1. Fill up text fields with the appropriate prompted information 2. Fulfill input requirements 3. Press the Login button to log-in or the Sign-Up button to register the account. 4. Displays Logging in or signing up. 5. Enter a username after selecting the Sign-Up button.	Users can create accounts successfully. Users can Sign in with the account registered. After Signing in, users are redirected to the home page. User information is saved in the database successfully.

6. Confirm the inputted username.

Table 2 shows the User Registration Module Test Results where users were able to properly register accounts and log on to the system. The results for the user registration module are similar to the expected results.

Table 3

Homepage Module Test Result

Steps Undertaken	Actual Result
1. Displays after the user logs in 2. Displays the username and picture of the user. 3. Choose between the Profile Info Tab or the Explore Tab	The Homepage Screen displays the user's name and picture accurately. Users can also explore and select a museum.

Table 3 shows the Homepage Module Test Results where users were able to properly navigate through the homepage section. The results for the homepage module were similar to the expected results, where the homepage screen contains the correct username and picture and selection of the museum.

Table 4

User Profile Info Module Test Result

Steps Undertaken	Actual Result
1. Select Profile Info tab from the Homepage 2. Read information displayed by the system 3. Displays visitation progress bars for each museum.	The Profile Info tab displays user information without data loss or errors. It also displays museum visitation progress and the list of

4. Select the checklist button shown beside the progress bar to view the user's list of visited galleries 5. Select the Log Out button to sign out of the account and redirect back to the User Registration	galleries/arts/sculptures/artifacts. Users can also log out of their accounts and be redirected back to the User Registration.

Table 4 shows the User Profile Info Module Test Results where users were able to properly navigate through the user profile section. The results for the user profile module were similar to the expected results, where the profile screen contains correct user information together with the visitation progress.

Table 5

Explore Tab Module Test Result

Steps Undertaken	Actual Result
1. Select Explore tab from the Homepage 2. Choose one out of the two national museums (Fine Arts or Anthropology) to visit	Buttons for the two national museums (Fine Arts and Anthropology), are displayed. Users are able to select one among the two national museums (Fine Arts or Anthropology) that they want to visit.

Table 5 shows the Explore Tab Module Test Results where users were able to select a museum and properly navigate through the galleries. The results for the explore tab module were similar to the expected results, where the explore tab contains the museum selection.

Table 6

Destination Selection Module Test Result

Steps Undertaken	Actual Result
1. Choose a museum from the Explore tab 2. Select the map button to pick a destination 3. Displays the map of the chosen museum 4. Input or select the artist, gallery, art, sculpture or artifact the user wants to visit 5. Check the optimal route to the destination generated by the system on the map 6. Select the gallery on the map for the info panel of that gallery to show up 7. Click the See Info button to redirect to the Inventory and view gallery info	Users are able to select/change a destination and guide the user to the destination. The generated optimal route to the specific destination is displayed. Users can also input specific artist, gallery, art, sculpture or artifact, which also displays the info panel.

Table 6 shows the Destination Selection Module Test Results where users were able to select/change a destination and guide the user to the destination. The results for the explore tab destination selection module were similar to the expected results.

Table 7

Inventory Module Test Result

Steps Undertaken	Actual Result
1. Choose a museum from the Explore tab 2. Select search button to view the inventory	Users can select among the floors and galleries in the Inventory and view the

3. Displays the inventory of the chosen museum 4. Select among the floors and galleries 5. View the arts/sculptures/artifacts in the gallery shown below 6. Click the *i* icon to view the info of a specific art/sculpture/artifact 7. Select the See on Map button to redirect back to the map and view the generated path	necessary information about the arts/sculptures/artifacts. Users can also be redirected back to the map and view the generated path to what they want to visit.

Table 7 shows the Inventory Module Test Results where users can select and view necessary information about artworks. The results for the inventory module were similar to the expected results where it displays artworks and artifacts depending on the user's choice.

Project Evaluation

A total of 70 respondents have evaluated the system, consisting of 10 IT/CS professionals, 40 IT/CS students, and 20 museum visitors which takes up to 14.29%, 57.14% and 28.57% of the population sample. Respondents evaluated the system based on the questions, which assure functional suitability, performance efficiency, usability, reliability, and maintainability of the system.

Table 8. ***Functional Suitability Responses***

	Mean	Interpretation
Functional Completeness	3.84	Highly Acceptable
Functional Correctness	3.7	Highly Acceptable
Functional Appropriateness	3.9	Highly Acceptable
Average	3.81	Highly Acceptable

Table 9. ***Performance Efficiency Responses***

	Mean	Interpretation
Time Behavior	3.77	Highly Acceptable
Resource Utilization	3.59	Highly Acceptable
Capacity	3.37	Highly Acceptable
Average	3.58	Highly Acceptable

Table 10. ***Usability Responses***

	Mean	Interpretation
Learnability	3.59	Highly Acceptable
Operability	3.66	Highly Acceptable
Average	3.63	Highly Acceptable

Table 11. ***Reliability Responses***

	Mean	Interpretation
Availability	3.72	Highly Acceptable
Fault Tolerance	3.6	Highly Acceptable
Average	3.66	Highly Acceptable

Table 12. ***Maintainability Responses***

	Mean	Interpretation
Reusability	3.63	Highly Acceptable
Modifiability	3.56	Highly Acceptable
Testability	3.7	Highly Acceptable
Average	3.63	Highly Acceptable

The system has been consistently rated as *highly acceptable* across all categories and aspects, which indicates that the system's performance was strong in terms of its *suitability, efficiency, usability, reliability, and maintainability.* Having high scores reflects that the system exceeded the user's expectations in different areas.

CHAPTER 5

RESULTS AND DISCUSSION

This chapter synthesizes and concludes the research findings from preceding chapters. It includes a comprehensive summary of findings, definitive conclusions, and informed recommendations for those interested in pursuing further research related to the Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Manila.

Summary of Findings

Based on the testing and evaluation procedures results, the Smart Directory Map Locator has successfully achieved its objectives, providing users with the optimal path to their destination and aiding them in their navigation in the museums. The system received favorable feedback from the CS/IT students and professionals as well as the museum visitors, although there is still room for improvement in terms of performance efficiency.

Conclusion

The researchers of this study conclude that "Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Manila" is well-received and highly acceptable in terms of *Functional Suitability*, *Performance Efficiency*, *Usability*, *Reliability*, and *Maintainability*, following the ISO 25010 criteria. After the evaluation, the researchers concluded that the Smart Directory Map Locator was successfully developed with the features for users (log-in system, shortest path, view gallery, and track visitation progress) and admins (admin log-in system, Fine Arts and Anthropology tabs, logout, and edit, save, and remove functions).

The map completely provided the necessary information, including labels and legends per floor, brief information about the place, information about the art/sculpture/piece and artist, and the established QR code for download link access of the finished application. The actual mobile application was also successfully developed using the developmental tools Godot 4, Firebase, and Android Studio. Lastly, the system was successfully tested and evaluated based on the ISO 25010 criteria, in terms of *Functional Suitability*, *Performance Efficiency*, *Usability*, *Reliability*, and *Maintainability*.

Recommendations

The researchers recommend adding other museums. They also recommend including iOS access to the application. The application may also become integrated with an interactive game that allows the users to take pictures at the museums and upload those photos of the artworks, artifacts, and sculptures in the application as another way of tracking their visitation progress.

APPENDIX A

Testing Procedure

System Function	Procedure	Expected Output
1. User Registration/Log in Page	1. Fill up text fields with the appropriate prompted information 2. Fulfill input requirements 3. Press the Log In button to log-in or the Sign Up button to register the account. 4. Displays Logging in or Signing up. 5. Enter a username after selecting the Sign Up button. 6. Confirm the inputted username.	Users must be able to create a new account and log in using their registered account. Specific text fields generate errors if specific input conditions are not satisfied. User inputted data is successfully stored to the database without errors or data loss. The application must be able to display the current status (i.e., Not Logged In, Logging in, Signing up, and Sign up success) of the user's log-in or sign-up process.
2. Homepage	1. Displays after the user logs in 2. Displays the username and picture of the user. 3. Choose between the Profile Info Tab or the Explore Tab.	The Homepage should correctly display the username of the user and contents of the Profile Info Tab. Users should be able to explore and select a museum they want to visit or view their user profile info.
3. User Profile Info Tab	1. Select Profile Info tab from the Homepage 2. Read information displayed by the system 3. Displays visitation progress bars for each museum. 4. Select the checklist button shown beside the progress bar to view the user's list of visited galleries 5. Select the Log Out button to sign out of the account and redirect back to the User Registration	The Profile Info tab should display user information without data loss or errors. Users should be able to view their museum visitation progress. The list of galleries that the user visited and checked off should be displayed after they select the checklist button beside the progress bar. They must also be logged out of their accounts and redirected back to the User Registration after pressing the Log Out button.
4. Explore Tab	1. Select Explore tab from the Homepage 2. Choose one out of the two	The Explore tab should display buttons for the two national museums (Fine Arts and

	national museums (Fine Arts or Anthropology) to visit	Anthropology). Users should be able to select one among the two national museums (Fine Arts or Anthropology) that they want to visit.
5. Destination Selection	1. Choose a museum from the Explore tab 2. Select the map button to pick a destination 3. Displays the map of the chosen museum 4. Input or select the artist, gallery, art, sculpture or artifact the user wants to visit 5. Check the optimal route to the destination generated by the system on the map 6. Select the gallery on the map for the info panel of that gallery to show up 7. Click the See Info button to redirect to the Inventory and view gallery info	Users should be able to select a destination. They should also be able to input the specific artist, gallery, art, sculpture or artifact they want to visit. The generated optimal route to the specific destination should be displayed, accurate, correct, and guide the user to the destination. The info panel should show up when a gallery on the map is selected. Users should also be able to change the destination if they desire to visit a different destination.
6. Inventory	1. Choose a museum from the Explore tab 2. Select search button to view the inventory 3. Displays the inventory of the chosen museum 4. Select among the floors and galleries 5. View the arts/sculptures/artifacts in the gallery shown below 6. Click the *i* icon to view the info of a specific art/sculpture/artifact 7. Select the See on Map button to redirect back to the map and view the generated path	Users should be able to select among the floors and galleries in the Inventory. The arts/sculptures/artifacts seen in the gallery should be displayed below. Users must be able to view the info of the specific art/sculpture/artifact in the gallery. After selecting the See on Map button, the user must also be redirected back to the map and view the generated path to what they want to visit.
7. Admin Log-in and Access	1. Log-in to access the museum admin website and go to the	Admins must be able to log in and out using their registered

	dashboard 2. Select either the Fine Arts tab or the Anthropology tab to see artwork information 3. Press the Add Info button to add an artwork information to the list 4. Press the Edit, Save or Delete buttons to update the information of a specific artwork 5. Click Logout tab to sign out of the admin account	account. Specific text fields generate errors if specific input conditions are not satisfied. They should be able to view the dashboard and choose among the tabs (Fine Arts and Anthropology) they want to access. Admins must be able to view, add, edit, save and delete information from the tabs.

APPENDIX B

Evaluation Procedure

Characteristics	Rating			
	4	3	2	1
A. Functional Suitability				
1. Functional Completeness. The software's functionalities cover all specified tasks and user objectives.				
2. Functional Correctness. The software provides results that are accurate based on the industry standard applications.				
3. Functional Appropriateness. The software's functionalities can be used for accomplishment of specified tasks and objectives.				
B. Performance Efficiency				
1. Time-Behavior. Time taken for the software to process data and give responses to its users.				
2. Resource Utilization. Software utilization and management of resources when performing its functions.				
3. Capacity. Maximum limitations of the software are				

enough to perform its functions.				
C. Usability				
1. Learnability. Degree to which the user can learn to operate the software with efficiency and effectiveness.				
2. Operability. Software design that affects the easiness of operating the system.				
D. Reliability				
1. Availability. Software is accessible when required for use.				
2. Fault Tolerance. The system operates as intended despite the presence of hardware or software faults.				
E. Maintainability				
1. Reusability. The software can be used to generate results that can be reused for other projects.				
2. Modifiability. The software can be modified efficiently without introducing defects or degrading existing product quality.				

3. Testability. Software’s effectiveness and efficiency can easily be tested through different test criteria.				

APPENDIX C

Survey Questionnaire Form

Survey Questionnaire

Good day!

We are fourth-year graduating students from the **Technological University of the Philippines - Manila**, pursuing a ***Bachelor of Science in Computer Science***. We are currently conducting research for our thesis, entitled "***Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Manila.***"

Our research involves the development of a smart navigation mobile application specifically designed for the National Museums of Manila. This application aims to provide a quick and efficient way to navigate through the extensive structures of the museums, making it easier for visitors to locate specific specimens, paintings, artifacts, and other exhibits. By utilizing the A* Algorithm, the application optimizes the shortest path, thereby enhancing the overall visitor experience.

The mobile application is intended to benefit a diverse range of users, including students, researchers, National Museum staff, and tourists from around the world. Your participation in our survey will greatly aid us in refining our application to better meet the needs of its users.

We kindly request your support by participating in our survey. The link provided below will direct you to a demonstration of our application.

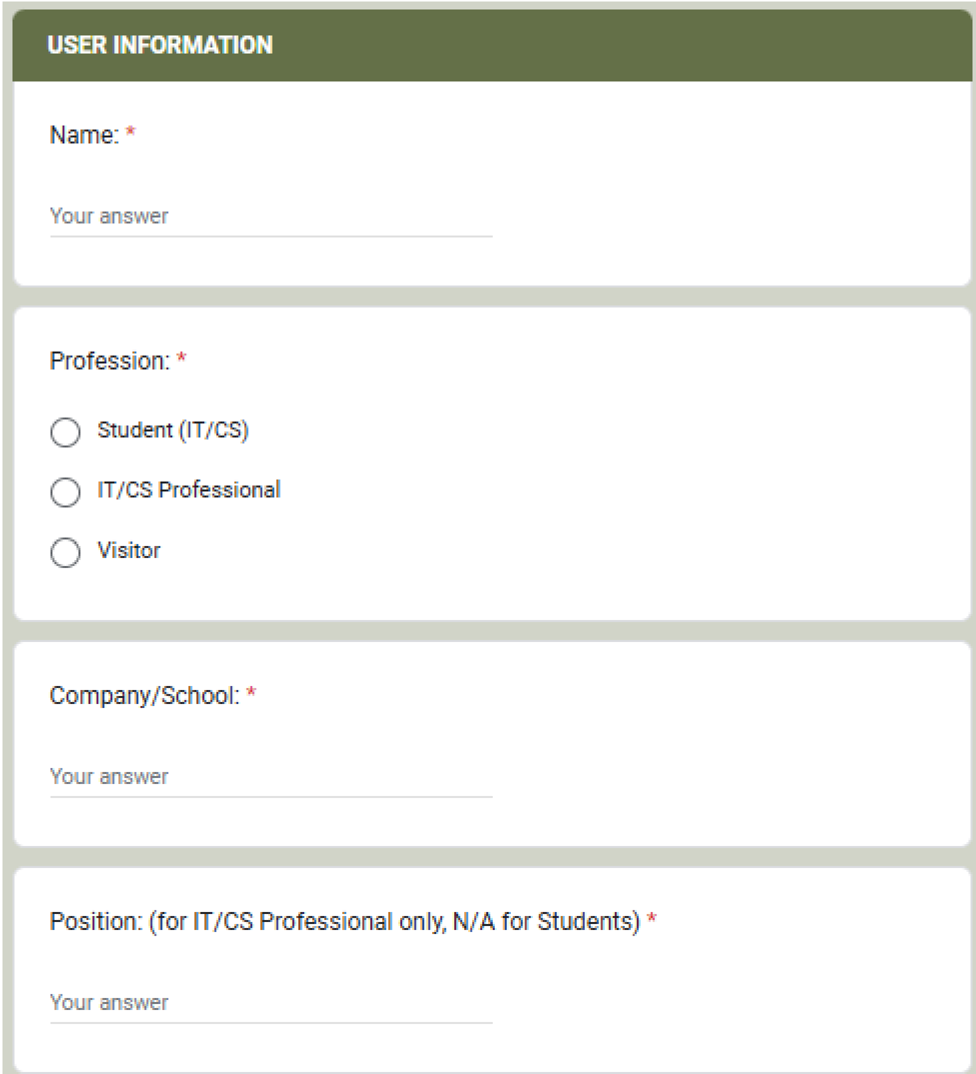
>>>>>> DEMO <<<<<<<<<<<

Thank you very much for your support.

BSCS-4B
Ermac, Andrea Jane L.
Julio, Natalie Kate L.
Lim, Randall Eira C.
Tacorda, Mark Cedrick B.

randalleira.lim@tup.edu.ph Switch account

Not shared



USER INFORMATION

Name: *

Your answer

Profession: *

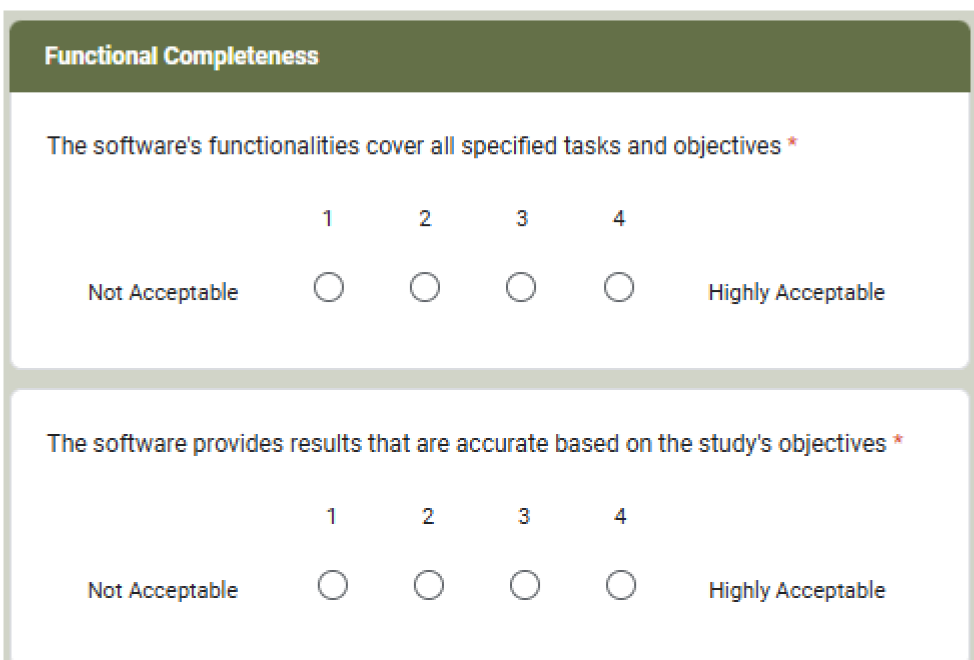
- Student (IT/CS)
- IT/CS Professional
- Visitor

Company/School: *

Your answer

Position: (for IT/CS Professional only, N/A for Students) *

Your answer



Functional Completeness

The software's functionalities cover all specified tasks and objectives *

	1	2	3	4	
Not Acceptable	○	○	○	○	Highly Acceptable

The software provides results that are accurate based on the study's objectives *

	1	2	3	4	
Not Acceptable	○	○	○	○	Highly Acceptable

Functional Appropriateness

The software's functionalities can be used for navigation *

	1	2	3	4	
Not Acceptable	○	○	○	○	Highly Acceptable

Time Behavior

Time taken for the software to navigate and give directions to its users *

	1	2	3	4	
Not Acceptable	○	○	○	○	Highly Acceptable

Resource Utilization

Software utilization and management of resources when performing its functions *

	1	2	3	4	
Not Acceptable	○	○	○	○	Highly Acceptable

Capacity

Maximum limitations of the software are enough to perform its functions *

	1	2	3	4	
Not Acceptable	○	○	○	○	Highly Acceptable

Learnability

Degree to which the user can learn to operate the software with efficiency and effectiveness *

	1	2	3	4	
Not Acceptable	○	○	○	○	Highly Acceptable

Operability

Software design that affects the easiness of operating the system *

	1	2	3	4	
Not Acceptable	○	○	○	○	Highly Acceptable

Availability

Software design that affects the easiness of operating the system. *

	1	2	3	4	
Not Acceptable	○	○	○	○	Highly Acceptable

Fault Tolerance

The system operates as intended despite the presence of hardware or software faults. *

	1	2	3	4	
Nit Acceptable	○	○	○	○	Highly Acceptable

Reusability

The software can be used to generate results that can be reused for other projects *

	1	2	3	4	
Not Acceptable	◯	◯	◯	◯	Highly Acceptable

Modifiability

The software can be modified efficiently without introducing defects or degrading existing product quality *

	1	2	3	4	
Not Acceptable	◯	◯	◯	◯	Highly Acceptable

Testability

Software's effectiveness and efficiency can easily be tested through different test criteria *

	1	2	3	4	
Not Acceptable	◯	◯	◯	◯	Highly Acceptable

APPENDIX D

Turnitin Result

Similarity Report

PAPER NAME

THESIS-GROUP-2_CHAPTER-1-5 (3).pdf

WORD COUNT 14505 Words	CHARACTER COUNT 79980 Characters
PAGE COUNT 78 Pages	FILE SIZE 4.2MB
SUBMISSION DATE Jun 10, 2024 10:08 PM GMT+8	REPORT DATE Jun 10, 2024 10:10 PM GMT+8

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● Excluded from Similarity Report

- Bibliographic material
- Quoted material
- Cited material
- Small Matches (Less then 20 words)

Summary

APPENDIX E

URDS Turnitin Certification

APPENDIX F

Thesis Grammarian Certification

	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Ayala Blvd., Ermita, Manila, 1000, Philippines Tel No. +632-5301-3001 local 608| Fax No. +632-8521-4063 Email: cos@tup.edu.ph | Website: www.tup.edu.ph	Index No.	
		Revision No.	
		Effectivity Date	
VAA-COS	**THESIS GRAMMARIAN CERTIFICATION**	Page	

This is to certify that the thesis entitled,

Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Manila

authored by

Ermac, Andrea Jane L.
Julio, Natalie Kate L.
Lim, Randall Eira C.
Tacorda, Mark Cedrick.

has undergone editing and proofreading by the undersigned.

This Certification is being issued upon the request of Ermac, Andrea Jane L. Julio, Natalie Kate L. Lim, Randall Eira C. and Tacorda, Mark Cedrick for whatever purposes it may serve them.

MS. FRANZE NAVARRO OROCEO
Grammarian

Technological University of the Philippines

June 11, 2024

Transaction ID	
Signature	

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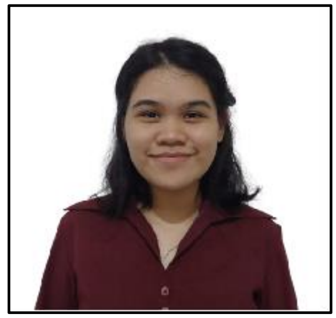

EDUCATIONAL BACKGROUND

Tertiary

Technological University of the Philippines – Manila
Ayala Boulevard, Ermita, Manila
Bachelor of Science in Computer Science
2020 – Present

Secondary

Rizal High School
Dr. Sixto Antonio Ave.Pasig, Metro Manila
STEM Strand
2018 – 2020

Rizal High School
Dr. Sixto Antonio Ave.Pasig, Metro Manila
2014 – 2018

SKILLS

Languages and Technologies: C, Python, HTML, CSS,Visual Studio Code, Github, Multimedia software (Adobe XD, Figma, Canva, Wix, WordPress)

AFFILIATIONS

Tertiary

Member, UX Society TUP Manila
Technological University of The Philippines – Manila
February 2022 – present

Secondary

English Journalism
Rizal High School
2016 – 2018

PROJECTS

Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Man
Thesis – QA, Data Gathering
October 2021 – Present

Land Division using Last Diminisher Algorithm
Lead Programmer
October 2022 – February 2023

TEAMBA Programming Language
Assistant Programmer
October 2022 – February 2023

Implementation of Sex Education in Web-based Learning Application for Pre-teens (9-11 years old) in Barangay Maybunga
Data Scientist
November 2022 – July 2023

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EDUCATIONAL BACKGROUND

Tertiary

Technological University of the Philippines – Manila
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Bachelor of Science in Computer Science
2020 – Present

Secondary

Olivarez College - Parañaque
Parañaque City
STEM Strand
2018 – 2020

Las Piñas National High School – Main (STEM Curriculum)
Las Piñas City
2014 – 2018

SKILLS

Languages and Technologies: C, C++ , Python, HTML, CSS, Javascript, Visual Studio Code, Github, Multimedia software (Figma, Canva, Wix)

AFFILIATIONS

Secondary

Student-Teacher in General Mathematics
Olivarez College - Parañaque
2019

Student-Teacher in Research II
Olivarez College - Parañaque
2020

PROJECTS

Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Man
Thesis – Project Manager, Front-end Dev
October 2021 – Present

Web-Based Application that Translates Basic FSL
Team Lead
January 2023 - July 2023

DrugProfiler: Mobile Application that Identifies a medicine, its use and side effect using CNN
Project Manager
October 2022 – February 2023

GayLingo Translator using Natural Language Processing
Project Manager
October 2022 - February 2023

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EDUCATIONAL BACKGROUND

Tertiary

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Bachelor of Science in Computer Science
2020 – Present

Secondary

De La Salle Araneta University
Victoneta Ave., Potrero, Malabon
STEM Strand
2018 – 2020

Philippine Cultural College - Caloocan Campus
8th Avenue Extension, Grace Park, Caloocan
2014 – 2018

SKILLS
Languages and Technologies: Assembly language, C, C++, Flutter (Dart), HTML, CSS, Visual Studio Code, Python, Arduino, and object-oriented programming, Multimedia software (Figma, Canva)

AFFILIATIONS

Tertiary

Member, TUP Gaming Enthusiasts Association Ring (TUP GEAR)
Technological University of the Philippines – Manila
October 15, 2023 – Present

PROJECTS

Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Man
Thesis – QA, Data Gathering
October 2021 – Present

Land Division using Last Diminisher Algorithm
Assistant Programmer
October 2022 – February 2023

TEAMBA Programming Language
Assistant Programmer
October 2022 – February 2023

Classifying Volleyball Hand Signals Using Convolutional Neural Network (CNN)
Assistant Programmer
October 2022 - February 2023

Implementation of Sex Education in Web-based Learning Application for Pre-teens (9-11 years old) in Barangay Maybunga
Data Scientist
November 2022 – July 2023

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EDUCATIONAL BACKGROUND

Tertiary

Technological University of the Philippines – Manila
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Bachelor of Science in Computer Science
2020 – Present

Secondary

Metro Manila College
Novaliches, Quezon City, Metro Manila
STEM Strand
2018 – 2020

Tala High School
Bo. San Isidro, Tala, Caloocan City, Metro Manila
2014 – 2018

SKILLS

Languages and Technologies: C, C++, Python, Flutter (Dart), Game Dev (Godot, GDScript), Tensorflow

AFFILIATIONS

Tertiary

Member, TUP DOST Scholars' Club
Technological University of The Philippines – Manila
February 2022 – present

PROJECTS

Smart Directory Map Locator with Navigation using A* Algorithm for the National Museums in Manila
Thesis – Main Programmer
October 2021 – Present

Web-Based Application that Translates Basic FSL
Assistant Programmer
January 2023 - July 2023

DrugProfiler: Mobile Application that Identifies a medicine, its use and side effect using CNN
Main Programmer
October 2022 – February 2023

Designing a Smart Campus Directory Application for the COS Building of TUP - Manila Using Ant Colony Optimization
Main Programmer
January 2023 - July 2023