computing@glyndŵr

Research Proposal for a Masters Dissertation

# Connor Laurence

## MSc in Computer Science

# Satnav Timetable app

# 23rd April 2021

# Abstract

Indoor Navigation applications have been in use for over a decade in many different environments but are typically closed and specially developed rather than open source and widely available. These systems are not without their problems however, indoor localization techniques using Wi-Fi are somewhat inaccurate due to scatter, signal attenuation and poorly developed Wi-Fi network infrastructures. This project seeks to determine whether the most current infrastructure-less localisation techniques coupled with a unique method for wayfinding provides a viable and feasible application for real world scenarios. The method for wayfinding – timetables – may prove an intriguing method for users such that environments you may typically use indoor navigation in (i.e., Universities, Bus stations, Train stations, Airports, Shopping Centres and Museums to name a few) could benefit tremendously. The feasibility will be determined by software testing to demonstrate a proof-of-concept application that demonstrates this method, its usefulness and perceived quality will be determined by mixed method user surveys.

# Introduction

Universities and other higher education establishments offer students various resources like timetables and campus maps. This project will explore the viability of indoor maps and navigation in an intuitive way by creating an android application that uses Web and PDF scraping to dynamically scrape Timetable content. This content could then be used to select a location within the university to then navigate to. Furthermore, navigation would provide multi-floor options, accessibility routes and clear routes to the nearest fire exits.

## Background

The artefact will be developed on Google’s Android platform for two main reasons; firstly, during the course projects have been undertaken by myself, and this has demonstrated relevant skills in Androids main programming language Java and secondly, Android as a platform has the lion share of the mobile OS market with nearly 72% share [1]. The other technologies that will be explored and used are; Indoor Mapping, Navigation, Web and PDF Scraping.

Indoor Mapping is a technology that builds on the ever-familiar outdoor navigation using GPS that most of us use. It takes an indoor venue and displays it on a 2D or 3D map so that users can see areas of interest, rooms, exits, entrances, lifts, and ramps to name a few. Solutions can be built to implement indoor positioning and thus navigation becomes possible [2]. Now large areas such as universities, shopping centres or stadiums to name but a few can be explored with a digital tool. This is not an innovative or new technology and has by and large seen some implementations in public buildings [3] however, the technology is not without its limitations. Limitations introduced by the method in which the indoor positioning is gathered (typically through Wi-Fi and GPS based systems) which can be heavily affected by thick walls, poorly placed access points and poor mobile signal [4].

This app aims to explore the viability of Indoor Mapping and Navigation at its current level of development commercially in a largely unique method of wayfinding – locating and navigating to a room from a timetable – and whether that would also be effective in aiding a student get around a campus to the right place on time. The latter two technologies work in tandem to both scrape the timetable content dynamically from the university timetable site and format the PDF into a usable format for navigation.

## Scope for Research

The main scope of research involves determining the viability of indoor navigation via timetable and whether it is possible to create an effective indoor navigation tool for students navigating via timetable. The Primary research element of this work will be centred around software testing to determine application viability for real world usage and end-user testing of the application which will survey users (depending on the number of testers) to determine whether; indoor positioning was accurate, navigation routes were useful, accessibility options were correct, timetable features worked and provided a unique positive method of wayfinding.

This would be useful to determine whether or not commercial indoor navigation solutions are accurate and viable enough in an indoor environment to use as a main user feature within applications or whether issues plaguing indoor positioning still affects these technologies. Also, it will determine whether navigating via timetable is an effective wayfinding method for students. This research may prove interesting to developers seeking to implement similar solutions, other students and faculty who may find an application like these useful and indoor navigation experts who may be seeking to validate current performance or seek feedback on improving indoor navigation solutions.

As a result of previously undertaking work within the android development environment, it is possible to conclude that this project will be feasible, challenging and rewarding within the current timeframe.

## Limitations

There are many commercial solutions available to implement indoor mapping and navigation that could be used, and this is not a project testing all such solutions but rather exploring each of the solutions and selecting one to implement within the application (likely the most common or popular solution available). Navigation or wayfinding will purely be accessed via the timetable system to eliminate extra factors and better evaluate the effectiveness of this method. Indoor Navigation will be limited purely to the main building as the floorplans provided only encompass this area.

## Ethical Issues

As the university floorplans are not immediately available to the public it is important to ensure the artefacts implementation does not change this. Solutions must allow ‘offline’ or access to the floorplans purely within the app and not make this available to all users of this service around the world. Location data will not be permanently stored and will ask user permission upon first use of application.

Any and all web-scraping will be of publicly available timetable information from the Universities timetabling system. Only timetables being searched for will be displayed to the user within app and navigation to rooms will be limited to lecturing rooms and labs available to all students and not to staff-only areas or staff offices. Timetable data will only be loaded dynamically and not stored offline unless selected by the user to store for later use.

When surveying end-users, data will be; collected anonymously, ask only relevant questions, make clear intention of the survey, only accept UK participants over the age of 16 as they can personally consent.

# Literature Review

This application is not the first to demonstrate usage of indoor mapping and navigation within a university or other large public building. The first implementation of an indoor maps app using a mobile phone for a university was actually a decade ago when the Norwegian University of Science and Technology (NTNU) developed a Campus Guide free for iPhone, Android and web users [5]. This system had an accuracy of 5-10 metres using a well-developed Wi-Fi network of over 1800 wireless routers. This first implementation worked off of user-driven innovation whereby all phases of the project were led by systematic user testing.

There are some universities today offering their students mobile apps for example the University of West Scotland [6] and Lancaster University [7]. These solutions are the typical navigate by search and rely on commercial solutions provided to the universities like the Netherlands-based Eyedog Indoor Navigation and MazeMap respectively. These solutions use advanced methods of acquiring indoor positioning such as Wi-Fi triangulation, BLE beaconing, sensor fusion platforms and geomagnetic field fingerprinting [8].

This application seeks to determine whether Infrastructure-Less methods such as GPS, Wi-Fi or AR – the least resistance route to setting up indoor navigation – is enough to enable indoor navigation and whether wayfinding is a niche but effective method of navigating a building like a university. For that purpose, there are three main technical aspects associate with its function which are Indoor Mapping, Indoor Navigation, Web and PDF scraping.

## Indoor Mapping and Navigation

Indoor mapping is a concept that visualises indoor spaces such as venues and spatial data on a 2D or 3D map [2]. Similar to how google maps or apple maps show the user outside information like buildings, roads and points of interest (POI) indoor maps show you places, rooms and indoor POIs. This is especially useful in large indoor venues like shopping malls and universities where it can become easy to get lost or difficult to find the location quickly [9].

Research into Indoor Mapping has been active for over three decades [10]. Initially, this technology was privy to engineers, contractors, and designers but increasingly commercial solutions have become the mainstay for this technology’s offerings [10]. Some solutions such as Google’s Indoor Maps [3] and Apple’s Indoor Maps [11] offer simple indoor maps to display information on websites and smartphones whereas other more in-depth commercial solutions like WRLD3D’s Indoor 3D Maps [12], Mapwize [13], Mapspeople [14] and MazeMap [8] offer Indoor Positioning and even wayfinding to enhance the users experience. Past commercial endeavours, these indoor maps solutions tend to be self-developed like in the previously mentioned case at NTNU which was initially started as a student project [5] or crowdsourced open-source projects like ‘Anyplace’ [15].

A map alone would not be entirely helpful to the user. If the user knew their location on that map, they could begin to see how useful a tool Indoor Mapping could become. The issue lies in acquiring the location of the user. Outdoor maps rely on global navigation satellite systems (GNSS) such as the Global Positioning System (GPS) [16]. GPS was first fully operational in 1993 and consists of a few dozen satellites orbiting the earth which compute positions in three dimensions and time offset [16]. This system is at best case scenario, accurate to within three metres given a variety of factors such as signal blockage, atmospheric conditions, and satellite geometry [17]. GPS accuracy drops even further when exploring its use within indoor environments. This is because buildings have thicker walls which in turn affect GPS signal [18]. Indoor accuracy is at best within 10 metres in an indoor environment [19]. This can be jarring to users experience as in a scenario like an indoor shopping mall or university, 10 metres could make it impossible to navigate by.

### Indoor Positioning Systems

Indoor positioning systems (IPS) supplant the use of GPS/GNSS within indoor environments. This is because these signals degrade quickly when they hit obstacles resulting in signal attenuation and scatter, further affecting the typical 1-3m accuracy achievable outside [20]. IPS uses different techniques and algorithms to achieve a position estimation calculated from signal strength or range. There a range of measuring principles used in detecting locations. These approaches either fall into the Infrastructure-Based or Infrastructure-Less categories depending on whether they need specialised equipment installed.

1. **Triangulation**

Triangulation uses the geometry of triangles to determine distance and orientation. This is done in two ways; Lateration and Angulation. Time of Arrival (TOA), Time Difference of Arrival (TDOA) and Angle of Arrival (AOA) are the most common techniques of triangulation, however, Received Signal Strength (RSS), and Return Time of Flight (RTOF) can sometimes also be used [20]. Lateration uses TOA to see the time it takes for signal to travel between multiple devices to calculate position of a target. Angulation uses AOA to determine target location by estimating the intersection of at which signals arrive at receiving sensors [20].

1. **Fingerprinting**

A successful technique used in IPS is radio fingerprinting [20]. This method is based on scene analysis where an area is mapped and analysed, signal properties in different locations are then collected and stored. When a device requests its location, device signal properties are compared to the database and the closest match provides an approximation of location [20]. Radio fingerprinting uses RSS which has a disadvantage of errors caused by radio signal scatter, multipath and attenuation [20].

1. **Signal Propagation Modelling**

Also known as radio propagation modelling, signal propagation modelling provides an alternative to the empirical form of fingerprinting previously mentioned. Instead, mathematical signal propagation models are made and based on theoretical computed signal strength data. User location is then estimated by matching signal strength measured in real-time [20].

1. **Dead Reckoning**

The oldest technique amongst these is dead reckoning. This relies upon estimation of current position based on a previously known position and estimated movement and direction since then. This is done by using the internal inertial sensor of a device like gyroscope, compass or accelerometer. Dead reckoning is rarely used in IPS systems due to small errors accruing and resulting in major errors in position estimation [20].

1. **Proximity**

Proximity location provides location based on distance to a known position in an area. Although not exactly accurate, the more known location devices and better sensitivity therein provide an increasingly accurate relative approximation of the location [20].

1. **Cooperative Positioning**

This approach uses other devices in a peer-to-peer system to share users position information. Using information gathered from the device’s vicinity, the device can estimate, improve accuracy and reliability of their position [20].

1. **Augmented Reality**

AR based solutions uses the devices internal sensors such as magnetic field, Wi-Fi signals and the inertial sensor as a hybrid approach and supplements the traditional 2D and 3D map approaches with a augmented reality approach to navigation [21].

The IPS systems of today typically use Wireless Local Area Networks (WLANs), Radio-Frequency Identification (RFID), Ultrasonic, Bluetooth, Inertial sensors, Ultra-wideband (UWB) or a Hybrid approach of these technologies [20]. WLANs using Wi-Fi networks to determine target positions typically via fingerprinting and signal propagation, though it is possible through triangulation too. The more access points and the better the placement of them, the more accurate this system is [20]. This method works well in large venue settings as these places typically offer free Wi-Fi. The latest advancements in this area of IPS is the use of Wi-Fi ranging with RTT [22]. Wi-Fi with RTT uses multilateration algorithms to determine user position in 2D/3D space.

RFID IPS systems uses passive, semi-passive or active RFID tags and proximity location to determine user position and at best provides a relative location. Like with WLAN, the more tags involved in the system the more accurate the location accuracy. Passive tags provide the least range but are attractive due to low level of maintenance [23]. The most famous models for IPS using RFID are LANDMARC [24] and SPOTON [25]. RFID systems fall foul of tag collision, cost and power consumption [26].

Ultrasonic systems can be highly accurate to the sub-centimetre scale [27]. An example of this is the TELIAMADE system which uses Time of Flight (TOF) of ultrasonic signals to estimate distance of receiver-transmitter nodes. By using triangulation through time synchronized TOF and multilateration techniques similar to Wi-Fi with RTT an accuracy of 9.6mm is achievable [27]. Ultrasonic is limited in larger scale environments due to the easy degradable signal’s which are dependent on signal-to-noise ratio, air and objects. Unless there are many beacons installed and good LOS is achieved, accuracy can degrade up to tens of metres [28]. Ultrasonic systems can be attractive due to the lower cost of ultrasonic based beacons and can also be a very good choice of complimentary support to another IPS system [28].

One of the most common and popular methods of IPS are Bluetooth Low Energy (BLE) beacons [29]. These low power sensors are cheap, can run on cell batteries and can be setup quickly and easily with minimal effort. These beacons use universal identifiers and multiple different beacons can be used in the same environment. These beacons can be accurate to 1-2 metres and use either proximity if minimal beacons are used or triangulation if there are many beacons in use [29].

Inertial sensors are perhaps the most inaccurate approach due to changes in gait distance or other factors affecting the device users’ passage to a destination. At best, if an Inertial based IPS is implemented well with a Model Wave and Particle Filter then accuracy of a traditional IPS system is capable of being reached [30].

Last but not least, geomagnetic field fingerprinting IPS systems are a form of signal propagation modelling type IPS’ [31]. This type of system very much depends on the stability of the magnetic field within the indoor environment. Studies show it is possible to discern between two overlapping floors [31]. Alone, this system can also fall foul of changes in the environment, objects users may be carrying, and objects being moved within the environment [31].

#### Indoor Navigation and Route Planning

Indoor Navigation or Indoor wayfinding is the guidance of a user in unknown building interiors and complexes. The user’s navigation system acquires its location from the IPS and displays a 2D or 3D map to the user. The users then either searches, select a POI and then a route is displayed on the map. The system updates the users position via IPS continuously [32]. The important function of a navigation system is to plot an optimal route given various inputs, in standard outdoor maps we may think of this as quickest, shortest or routes without tolls. In an indoor map, this may include the typical quickest but also may include accessibility options like lifts and ramps or multi-floor routes [33].

Pathfinding techniques are an essential part of any navigation-based application. Complex indoor environments have increasingly complex demands on route planning methods such that IFC-based path planning, semantically enriched indoor navigation, context-aware indoor navigation, and indoor route planning method with environment awareness have all arisen to the challenge of improving the users experience [34]. Typically, an indoor route plan will be based off of geometric models to provide an optimal route. This can be done by feeding environment semantics into algorithms like Dijkstra [34], A\* or ACO [35]. Route planning can be considered like networks are in that doors and rooms are nodes and corridors are edges [34] [36]. This allows for optimal pathing based on shortest distance and time like you would do for network design, and also environment variables like accessibility aspects of a building’s floorplan. Graph based models like Symbolic modelling can establish a structure based off reference points like rooms to carry out distance computation more accurately. This allows for direct usage of graph algorithms like shortest path, traversals, and connectivity [37].

#### ARCore and SLAM Indoor Navigation

Aside from these techniques mentioned above, some modern solutions are making the most of the user’s smartphone functionality in indoor navigation. From Android 7.0 onwards, ARCore can be used to build augmented reality experiences. If not immediately evident, ARCore enables the phone to sense its environment in three key aspects; motion tracking, environmental understanding, and light estimation. Using these aspects, it becomes rather easy to see that the tracking of the device as it moves and the building an understanding of the real world can be useful to creating infrastructure-less indoor navigation tools [38]. ARCore’s motion tracking uses both the camera to identify interesting points and the device’s inertial sensors to determine position and orientation of the device as it moves through space [38].

SLAM Sensors + Anchors? – Visual-Inertial Odometry (VIO)

<https://developers.google.com/ar/discover/concepts#motion_tracking>

AR toolkits – ARCore, ARKit, Wikitude, Vuforia rise in recent years

<https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8813348>

## Web Scraping and PDF Parsing

The web is considered a huge information source for many people coming from many backgrounds. Containing useful information amongst a huge swathe of structured and unstructured information in varying different formats. Web Scraping is a tool used to retrieve and format this data to best suit our usage and application [38]. Web scraping itself is just the process of acquiring this data, the method could be manual like using a search engine or to some degree automated like a software-based web scraping tool.

Different approaches to web scraping include mimicry, weight measurement, differential, and machine learning. Mimicry is the scraper that works with predefined rules whereas the others work largely on an algorithmic based approach [38]. Web scraping is a relatively easy to access field with ready-made tools from many different providers for out the box scraping with little configuration [38]. One such tool – JSoup - is an easy-to-use open-source scraping tool that works well in an android environment [39].

In terms of formats, Web scraping can scrape all the content of a site unless specifically blocked. This could involve basic html like text information, pictures, and other embedded content such as PDFs and download links. This information may be really useful but without a method of parsing the content like text extraction of a PDF document or an embedded player to show videos and pictures, integrating web scraping into a dynamic product can be somewhat difficult. PDFs are perfect for cross-compatibility across devices being “portable, platform independent and human-readable” [40]. The format is largely unstructured which makes analysis of these documents somewhat difficult. Ready-made tools and libraries are also available in this area, one such tool is Apache PDFBox which is a Java based library that works in android development environments [41].

## … Analysis and Conclusions

In the context of this application, the research has led to some conditions that we can pre-define. Due to the limitation of budget and the requirement for some decent level of accuracy, an infrastructure-less and free or open-source solution to indoor navigation is necessary. This could be solutions like *Anyplace* – with an accuracy level of 1.96m [42] or *ARCore* based approaches [43] have been used to great effect in an android application. Secondly, in terms of web scraping tools, JSoup is a great open-source tool that can achieve the goal of dynamically scraping timetable content [39]. Finally, when extracting information from the scraped PDF files, PDFBox is an excellent open-source tool to carry out text extraction from PDF files [41]. Together, these three tools should provide an excellent basis for developing this application and determining the effectiveness of timetables as a method of wayfinding and whether the application is viable enough for real world usage.

# Research Hypothesis and Questions

This project aims to determine whether ‘Timetables’ are a viable method of wayfinding in an indoor environment. By ‘Timetables’, would a user searching for their timetable and selecting rooms be an intuitive approach to navigating to rooms in an indoor environment. By using a widely available and open-source solution to indoor navigation, the project also seeks to determine if the infrastructure-less approach of using Wi-Fi, GPS and inertial sensors provide an accurate enough indoor positioning system to the app to provide a viable ‘Timetable Satnav’ Android application.

The research hypothesis will be determined from primary research in the form of software testing of the application and the associated research questions will be determined from further user testing of the resulting android application. A viable solution should be considered as one that allows the user to navigate without issue within an indoor environment without getting lost.

## Research Hypothesis

It is possible to create a ‘Timetable Satnav’ Android application

## Research Questions

1. Is Wi-Fi viable enough for indoor navigation?
2. Is wayfinding via timetables an effective method of navigation?

# Methodology

Good projects tend to plan well in advance. This typically involves the use of methodologies. These methodologies generally fall into one of two categories: hard or soft approaches. Hard approaches

Involve strictly defining the problem to be solved and rigid techniques and procedures to developing solutions. Soft approaches form a looser framework of tools which are more appropriate to problems with fuzzy requirements [44].

This project would better suit a hard approach given its defined problem of implementing a wayfinding method in an indoor navigation system. Given the time and resource constraints for the project and the essential need for an artefact as a deliverable, a methodology which prioritises presenting working software over documentation such as an Agile methodology would be well suited to the project [45].

Agile methodologies like Scrum expand on the older Agile methodology [46]. The Scrum process involves scrum artifacts, roles, events, and the daily scrum. The artifacts involve the Product backlog (a prioritized list of system requirements) and Sprint backlog (functional and non-functional customer and technical requirements). The roles encompass three types; Product Owner, Team Member and Scrum Master. The product owner represents the stake holders, team member is self-evident and Scrum master coaches the team through following the scrum process [46].

Scrums work in units defined as sprints. These are set periods of the development, each with a sprint backlog, sprint goal and sprint meetings. These tie in with Minimum Viable Product (MVP) which is an objective to deliver a product at each level of development [47]. Should sprints overrun or time constraints affect the project, MVP ensures that a deliverable of some level is at least delivered.

This project will be developed in the Android development environment. Further research and experimentation with specific solutions for indoor navigation will need to be carried out to ascertain the most appropriate solution to use. Other tools used included *Apache PDFBox* (an open source java tool for working with PDF documents) [41], *JSoup* (an API for fetching URLS, extracting and manipulating data) [39], *SQLite* (a free public domain SQL database engine) [48] and the *JAVA* programming language [49].

A development methodology ensures a strong defined process which will aid in producing deliverables, however, this does not guarantee that the deliverable meets the requirements either set by the customer or by the larger research goals. Research methods are designed to try to determine those research goals. These can encompass largely Qualitative or Quantitative approaches [50]. The Qualitative approach is centred around gathering quality data, this can be done through interviews and expert feedback. The Quantitative approach is centred around quantity of data and can be gathered by surveys and experiments generally [51]. Both have their positives and drawbacks such that another research method: Mixed-Methods was developed to try and achieve the best of both scenarios. This could be done in the form of a survey gathering quantitative data and including open ended questions to gather qualitative data [52] [53].

## Requested Supervisor

Julie Mayers

## Preparation

Further research and experimentation into indoor navigation solutions like *Anyplace* [54]*, Navigine* [55]*, ARCore* [43]and the surrounding literature around these open-source projects will be necessary to gain a fundamental understanding into the setup, technical aspects and which is best to integrate into the new application. Further expansion into the literature review above may be necessary depending on what is discovered during this stage.

Having acquired the university’s floorplans, they will need to be adjusted to suit the constraints of the project. Since the application uses timetables as a method of wayfinding, timetabled rooms become the POIs and as such, only publicly accessible portions of the building need to be displayed. For Wrexham Glyndŵr University, these buildings include Blocks A, B, C, D, E, L, K, M, and the student union. Of these, timetabled rooms are only found in Blocks B, C and E. Since the student union and E block are external to the main building, further analysis is necessary to determine whether it is prudent to include them within the scope of this application and how this may be done with overlap of an external navigation tool working in conjunction with this application. Initially, Blocks B and C may be included as POIs on the floorplan and depending upon time constraints, Block E may later be added as an extension. This may be considered as ‘Minimum Viable Product’ levels of development [47] or as a proof of concept.

Once the floorplan is adjusted, they will be uploaded and kept private on the device or a server. Once uploaded, all the relevant timetabled rooms associated with the adjusted floorplans will be added as POIs. For Anyplace this can be done using the Anyplace Architect web app that enables users to design and upload building structures to Anyplace [42]. Navigine has a similar method for creating POIs too through their developer portal. ARCore uses Unity or other tools to implement the map where you place markers on to relate to POIs [56].

Once the map is setup, most solutions require setup with regards to localization. This might be similar to developing an RSSI map made up of a number of sensors results such as Wi-Fi, BLE, Fingerprinting, AR mapping and inertial sensors or even a hybrid approach of these. This map could then be later accessed by the application to estimate current user position based on previous sample data. RSSI maps rely on collecting and processing this data in sample runs covering the whole navigational area to be effective in any regard.

ARCore based indoor navigation can work in a number of ways. Some solutions use the Tango platform with Area Learning [56], QR codes for instant start positions and NavMesh in Unity for pathfinding [57] or even using the localisation techniques found in other solutions like *Anyplace* and *Navigine* like RSSI fingerprinting*.*

Anyplace uses a ’Logger’ app to crowdsource location-tagged data [42]. Prior to setting up the application, sensing campaigns will need to be undertaken within the university. This will require walking around each of the areas designated as being included in the floorplan while connected to the university’s Wi-Fi infrastructure. This process will create Wi-Fi Radiomap’s which can in turn be reviewed by the user to determine if a sufficient sample of data is acquired for the floorplan. Upon collection and verification of the data, the user can then upload this data to the cloud service through a Web 2.0 API [42].

## Top-Level Design

After initial setup of floorplans and Wi-Fi Radiomap’s, it will be essential to discover how to integrate *Anyplace* Navigator [42] into the new application. This will involve understanding how to determine user location within the indoor environment using the solution’s IPS. This will be done in an ethical manner with regards to location privacy and not storing that data for later use [58]. IPS will be a core component of the application, firstly by acquiring initial location and secondly by periodically updating the position of the user while en route to a destination.

Once location is acquired, Modelling becomes necessary to deal with the associated complexity of an indoor environment. This could include anything from walls, stairs and doors to escalators, elevators and ramps [59]. This modelling ties in with the *Anyplace* Architect involved in the setup. This tool provides an interface to “upload blueprints, annotate and geo-tag POIs and connect them to indicate feasible paths” within the university [42]. To maintain the University’s floorplan privacy, these can be shared privately using a URL such that users who may be mapping the university can do so privately. The directions can rely on modelling in two ways; automated indoor model checkers (this is like the previously mentioned graph connectivity where graph based models work similar to network modelling with nodes and edges) [37] and modelling led by user input – in this case, using the *Anyplace Architect* to upload routes alongside POIs and other data [15].

The integration of timetables with the Indoor navigationwill replace searching for a POI with a user selecting a room from a timetable they have searched for and automatically automate the search process and select a suitable route for the user to navigate by.

Meanwhile, in the leadup to this integration, on load the application will scrape the university timetabling website using JSoup, collate all of the associated PDF files with their data attributes into a SQLite 3 database linked to a list similar to Androids listview. From here, PDFBox will be used to extract text from those files when selected and format the information to a usable interface. Each of the rooms within that timetable will be linked to the integration mentioned above. Should a room not be available among the POIs for any reason, an error message should be displayed showing that room could not be found.

The last component of the app will later aid in the user testing stage of the artefact. Integrating an activity in the menu which leads to a WebView showing a Google Forms survey will streamline the process of user testing and will aid in the acquisition of data associated with the app’s user testing necessary to determine the hypothesis of this project.

## Development

This application will be developed using the principles of Minimum Viable Product [47] in an Agile development environment. This will suit to the timeframe for dissertation and should guarantee an artefact that demonstrates ability to prove the hypothesis at the very least as a proof of concept. Primary research Data will be acquired through software testing and a survey. Within the app, functionality for completing this survey will allow the user to anonymously carry out a mixed methods-based survey, the user will be notified they have to be over the age of 18 to consent to participate, that their responses will form part of a small research study to determine the above-mentioned research questions and that the data will only be made accessible to the researcher and research supervisor if necessary.

The stages of minimum viable product will likely involve stages such as:

**Stage 1** – Artefact has timetable scraping, selection and can search and show location of room on map as well as current user location. Map limited to Block B for POIs. Artefact is considered Proof of Concept.

**Stage 2** – Artefact as above except also shows navigation routes for user to get to desired destination location.

**Stage 3** – As above, except includes Block C and navigation to all main building entrance/exits. Accessibility routes also included for preference navigation by Lift/Ramp. Evacuation routes to nearest fire exits included.

## Testing

Mixed Methods research is a research design that aims to gather both qualitative and quantitative research [52]. Both qualitative and quantitative research have positives and drawbacks, as such, a mixed methods approach can gather research with the benefits of both approaches. Given this project is being undertaken during a pandemic and the hypothesis is largely centred around the feasibility of the app, the survey will be focused on the research questions associated with the project.

The app’s feasibility and the projects main hypothesis will be by and large proved by the artefact’s performance in various software testing techniques. There are many different techniques and standards that can be used to great effect. The main premise around testing will be to create test plans during the project to test each of the components and functionality of the end artefact [60]. Some involve breaking it down into small chunks known as unit testing where other cover aspects such as UI and UX as well as function and security testing.

For this artefact, test plans should follow the minimum viable product principles and at the very least cover manual testing like the black box testing approach (also known as system testing), black box testing with unit tests and integration testing between the timetable web-scraping elements and the indoor navigation service [60].

The research questions will be determined by surveying the users. Should the number of users be insignificant which is a large possibility given the nature of its usage and the environment in which it is to be used, qualitative answers can demonstrate more detail in relation to the app with thematic analysis. Quantitative answers can simply demonstrate binary answers like yes and no or Likert scale responses for less complicated answers needed.

The data will be made available only to the main researcher and research supervisor upon request. It will be stored on a google forms survey linked to a private google sheets document.

## Evaluation

The Research Hypothesis will be determined largely by the software testing aspect. Should the artefact pass all software test plans, it would demonstrate that it is possible to create a viable timetable satnav application as a proof of concept and that there is real world potential for this type of wayfinding in this type of application. If it fails, then it may highlight areas for improvement or where the project and artefact may have failed.

The additional user testing will determine whether or not the additional research questions which are more dependant upon human elements in these questions: “Are Wi-Fi and GPS viable enough for indoor navigation?” and “Is wayfinding via timetables an effective method of navigation?”.

For the main hypothesis, it is very unlikely for a inconclusive result as the functionality either works or it doesn’t. Some issues like the set-up of infrastructure may affect accuracy somewhat but should not affect the overall capability to determine user location and navigation by timetable wayfinding.

The ancillary research questions on the other hand run a much larger risk of proving inconclusive. With the current limitations of the pandemic, the lack of users is a very real issue. Even trying to offset this by seeking more qualitative results, social distancing and user retention are still an aspect to cope with and risk analysis will be necessary to try and mitigate an inconclusive response.

Any unproven outcome derived from the survey would not affect the research contribution as the main research hypothesis is largely not affected by this outcome. This is because the original aim and main objective is tied to the real-world feasibility of the app. Software testing will provide the primary research results to determine the viability of the app and whether it even works in this setting.

## Reporting Results and Conclusions

Given that this dissertation project is being undertaken during a pandemic, it is likely that a face-to-face demonstration as you would typically see with other artefacts would not be possible. Given the circumstances, results will have to be conveyed via an online demonstration such as a meeting on Microsoft Teams.

This highlights another issue in that given the nature of the artefact and its essential requirement to be within the university grounds to demonstrate functionality, a pre-recorded artefact demonstration must be made. This demonstration would have to go through each of the artefact’s elements of functionality.

Aside from the pre-recorded artefact demonstration video, the results from both the user survey and the software testing should be tabulated and put into a presentation of sorts in order to report those results more effectively in a live online demonstration with the research supervisor and other audience who may be involved. Here, the dissertation project can be shown through the demonstration video and later defended if and when questions arise.

## Project Planning and Timescales

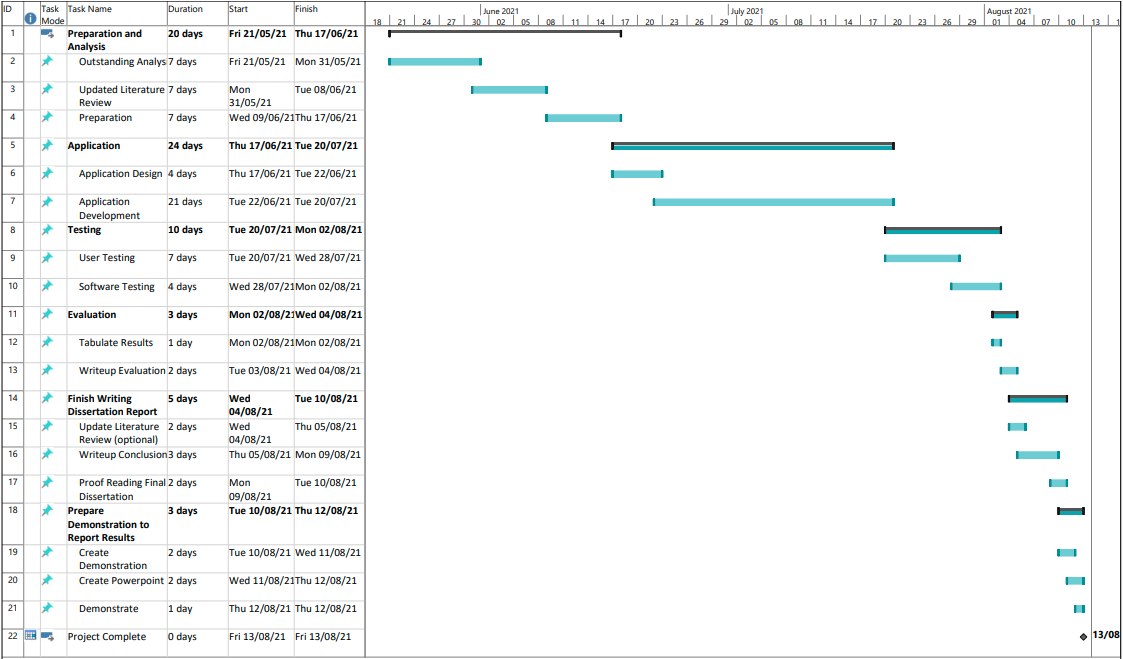
Current deadline for this project is earmarked for mid-august 2021. This means the project timeline is around 11 weeks long. Putting the project planning deadline a week or so in advance and building in slack to some units allows for some leeway in extending some time aspects as and when it may be needed but for the most part the project timeline is as follows.

Figure 1 - Gantt Project Chart

## Risk Analysis

Risk analysis is an important process to help identify and manage potential problems during a projects software development life cycle (SDLC). Risk analysis aims to avoid, minimize, and monitor risks and their associated impacts [61]. It is important to identify areas of risk, determine their likelihood and severity and discuss mitigation techniques for preventing or offsetting the impacts associated.

|  |  |  |  |
| --- | --- | --- | --- |
| RISK | LIKELIHOOD | SEVERITY | MITIGATION |
| Unable to get enough user testers | High | Moderate | Qualitative approach for better quality data  Include self in user testing |
| Connectivity Issues – | Low | High | Set up own server if required. Adapt to infrastructure-based environment and limit area of use – i.e., implement BLE beacons |
| Unit of work takes longer than expected | Moderate | Moderate-High | Adjust project planning accordingly and start time-crunching  Follow a development methodology and allow for Minimum Viable product stages |
| User Survey inconclusive | High | Moderate | Demonstrate why inconclusive and extrapolate useful conclusion therein. |
| Repetitive Strain Injury (RSI) and Eye Strain | Low | High | Adjust workstation to promote good posture. Take regular breaks. |
| Insufficient QA and Testing time | Moderate | High | Adjust project planning |

# Ethical Approval

## Components Requiring Ethical Approval

As this dissertation project contains an element of direct primary research gathering involving people in a user survey. It is important the project attains ethical approval in accordance with Wrexham Glyndŵr University’s Code of Practice on Ethical Standards [62]. The component requiring ethical approval directly involves people in a user testing survey.

The ethical approval is important two-fold. Firstly, it guides the researcher to carefully consider the ethical implications of their research [63] and secondly, it ensures that participants of the research are given maximised benefit and minimised harm [64] – preferably none whatsoever.

Researchers carrying out user surveys will be obligated to main confidentiality and acquire informed consent [65]. Informed consent should invite the user to participate, inform the user of the research studies goal(s), name the researcher(s) (and funding if any), highlight any qualifiers required to undertake the study and let the user know it is voluntary [66]. Furthermore, qualifiers will likely include age restrictions due to the age of consent or will supply an enhanced level of informed consent with the underaged persons parent or guardian.

Confidentiality is associated the protection of user data acquired during the survey period. Data taken in should only be necessary to the research study, an anonymous survey would-be best-case scenario, however, if identifying information is taken in, it is the responsibility of the researchers to protect this information in accordance with “The Data Protection Act 2018” [67].

For this project, a user survey through ‘Google Forms’ will be sufficient to both inform consent, gather survey responses and safely store information gathered. Informed consent shall highlight the studies name, purpose, researcher’s information, and goals while highlighting the need for the respondent to be over 18 to participate. The user survey can be initiated from within the app after the user has progressed and is voluntary.

The user testing will likely cover only a few users, however, full consideration for current coronavirus regulations at the time of the testing period will be adhered to and other aspects of the app’s nature like user location will also adhere to the Data protection act and will only localise the user on the users device when in use and when not in use, that data will not be stored.

|  |  |  |
| --- | --- | --- |
| Ethical Issues | Risks posed | Mitigation |
| Informed Consent | Consent may be given by minors or users without being properly informed | Inform user of study name, purpose, goal, researcher(s)  Inform user to be 18+ to participate |
| **Confidentiality** |  |  |
| * User Information and Data Handling | Information may include irrelevant, yet potentially harmful data | Ensure adherence to data protection, only take in data necessary to study |
| * User location | User information gathered during apps usage may prove useful to malicious actors | Ensure localisation only in use with user permission and when functionality requires |
| Coronavirus Regulations | No adherence to these regulations at this time may prove negative to user’s health | Adhere to current coronavirus regulations at time of user testing period |

## Action to Obtain Ethical Approval

To get Ethical Approval, an “Ethical approval of research projects in taught programmes” form will have to be completed and sent to the research supervisor. If the ethical issues are considered minor risks and the mitigation and risk analysis is well considered, either the research supervisor or module leader may be able to approve it. If not, then the project will be escalated to the universities research ethics committee, leeway is put into the planning and timelines for the project as there is a four-week gap between proposal submission and official start date for the dissertation. A pre-filled ethical approval form can be found in the appendix below for the dissertation project.

# References

|  |  |
| --- | --- |
| [1] | S. O'Dea, “• Mobile OS market share 2019 | Statista,” Statista, 08 02 2021. [Online]. Available: https://www.statista.com/statistics/272698/global-market-share-held-by-mobile-operating-systems-since-2009/. [Accessed 05 03 2021]. |
| [2] | S. Pichler, “ArcGIS Indoors 2D/3D Indoor Maps powered by Esri,” 30 04 2019. [Online]. Available: https://www.esri.com/arcgis-blog/products/arcgis-indoors/mapping/what-is-indoor-mapping/. [Accessed 05 03 2021]. |
| [3] | Google Maps, “Indoor Maps availability - Google Maps Help,” Google, [Online]. Available: https://support.google.com/maps/answer/1685827?hl=en-GB. [Accessed 05 03 2021]. |
| [4] | B. Ray, “How Indoor Positioning Systems Work & Types of Location Tracking,” 16 08 2018. [Online]. Available: https://www.airfinder.com/blog/indoor-positioning-system. [Accessed 05 03 2021]. |
| [5] | NTNU, “Campus guide - NTNU,” 31 08 2011. [Online]. Available: https://www.ntnu.edu/news/campus-guide. [Accessed 02 04 2021]. |
| [6] | University of West Scotland, “News | UWS introduce new app for indoor navigation,” [Online]. Available: https://www.uws.ac.uk/news/uws-introduce-new-app-for-indoor-navigation/. [Accessed 02 04 2021]. |
| [7] | L. Hodge, “Lancaster University and MazeMap: Paving the Way for Innovation,” 08 09 2020. [Online]. Available: https://blog.mazemap.com/lancaster-university-and-mazemap/. [Accessed 02 04 2021]. |
| [8] | MazeMap, “Indoor positioning,” [Online]. Available: https://www.mazemap.com/solutions/indoor-positioning. [Accessed 02 04 2021]. |
| [9] | P. Julia, “What is the Indoor Mapping - Blog Geographica,” 27 04 2017. [Online]. Available: https://geographica.com/en/blog/indoor-mapping/. [Accessed 04 04 2021]. |
| [10] | S. Zlatanova, G. Sithole, M. Nakagawa and Q. Zhu, “Problems in Indoor Mapping and Modelling,” in *ISPRS Acquisition and Modelling of Indoor and Enclosed Environments*, Cape Town, South Africa, 2013. |
| [11] | Apple, “Apple Business Register,” [Online]. Available: https://register.apple.com/indoor. [Accessed 04 04 2021]. |
| [12] | WRLD3D, “3D Indoor Maps | WRLD3D,” [Online]. Available: https://www.wrld3d.com/3d-maps/indoor-mapping#Indoor-3D-Maps. [Accessed 04 04 2021]. |
| [13] | Mapwize, “Indoor mapping & Wayfinding for Smart Buildings,” [Online]. Available: https://www.mapwize.io/. [Accessed 04 04 2021]. |
| [14] | Mapspeople, “MapsIndoors - Indoor navigation with Google Maps - MapsPeople,” [Online]. Available: https://www.mapspeople.com/mapsindoors/. [Accessed 04 04 2021]. |
| [15] | K. Georgiou, T. Constambeys, C. Laoudias, L. Petrou, G. Chatzimilioudis and D. Zeinalipour-Yazti, “Anyplace: A Crowdsourced Indoor Information Service,” in *16th IEEE International Conference on Mobile Data Management*, Pittsburgh, 2015. |
| [16] | Princeton, “Microsoft Word - gnss-2-09-06 final.doc - GNSS.pdf,” 14 02 06. [Online]. Available: https://www.princeton.edu/~alaink/Orf467F07/GNSS.pdf. [Accessed 04 04 2021]. |
| [17] | Rewire Security, “Accuracy, Precision and Reliability of GPS Tracking and GPS Tracker,” 07 02 2019. [Online]. Available: https://www.rewiresecurity.co.uk/blog/gps-tracking-tracker-satellite-accuracy-precision. [Accessed 04 04 2021]. |
| [18] | G. Dedes and A. Dempster, “Indoor GPS positioning - challenges and opportunities,” in *IEEE 62nd Vehicular Technology Conference*, Dallas, 2005. |
| [19] | M. Piras and A. Cina, “Indoor Positioning using low cost GPS receivers: Tests and statistical analyses,” in *International Conference on Indoor Positioning and Indoor Navigation*, Zurich, 2010. |
| [20] | L. Batistic and M. Tomic, “Overview of indoor positioning system technologies,” in *41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, 2018, 2018. |
| [21] | X. H. Ng and W. N. Lim, “Design of a Mobile Augmented Reality-based Indoor Navigation System,” in *4th International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*, Istanbul, 2020. |
| [22] | D. Campbell, “Indoor positioning with WiFi RTT and Google WiFi | by Darryncampbell | Medium,” 4 10 2019. [Online]. Available: https://medium.com/@darryncampbell\_83863/indoor-positioning-with-wifi-rtt-and-google-wifi-a638f1147b84. [Accessed 07 04 2021]. |
| [23] | S. Saab and Z. Nakad, “A Standalone RFID Indoor PositioningSystem Using Passive Tags,” *IEEE Transactions on Industrial Electronics,* vol. 58, no. 5, pp. 1961-1970, 2011. |
| [24] | M. N. Lionel, Y. Liu, Y. Lau and A. Patil, LANDMARC: Indoor Location Sensing Using Active RFID, Netherlands: Kluwer Academic Publisher, 2004. |
| [25] | J. Hightower, C. Vakili, G. Borriello and R. Want, Design and Calibration of the SpotON Ad-Hoc Location Sensing System, 2001. |
| [26] | P. Daas and D. Agrawal, “RFID for Indoor Position Determination,” in *Second International Conference on Advanced Computing, Networking and Informatics*, Kolkata, 2014. |
| [27] | C. Medina, J. C. Segura and A. d. l. Torre, “Ultrasound Indoor Positioning System Based on a Low-Power Wireless Sensor Network Providing Sub-Centimeter Accuracy,” *Sensors,* vol. 13, no. 3, pp. 3501-3526, 2013. |
| [28] | D. Gualda, J. M. Villadangos, J. Urena, A. Jimenez, F. Seco and A. Hernandez, “short47.pdf,” 2019. [Online]. Available: http://ceur-ws.org/Vol-2498/short47.pdf. [Accessed 07 04 2021]. |
| [29] | A. A. Kalbandhe and S. Patil, “Indoor Positioning System using Bluetooth Low Energy,” in *International Conference on Computing, Analytics and Security Trends (CAST)*, Pune, 2016. |
| [30] | Y. Sun, Y. Zhao and J. Schiller, “An Indoor positioning system based on inertial sensors in smartphone,” in *IEEE Wireless Communications and Networking Conference (WCNC)*, New Orleans, 2015. |
| [31] | J. Chung, M. Donahoe, C. Schmandt, I.-J. Kim, P. Razavi and M. Wiseman, “Indoor location sensing using geo-magnetism,” in *Proceedings of the 9th International Conference on Mobile Systems, Applications, and Services (MobiSys 2011)*, Bethesda, 2011. |
| [32] | C. Hallstrom, “What is Indoor Navigation? The Complete Guide 2020 - NEARMOTION,” 06 06 2020. [Online]. Available: https://nearmotion.com/news/what-is-indoor-navigation/. [Accessed 07 04 2021]. |
| [33] | M. H. V. Le and D. Saragas, “Indoor\_Navigation\_System\_for\_Handheld\_Devices.pdf,” 22 10 2009. [Online]. Available: https://web.wpi.edu/Pubs/E-project/Available/E-project-102209-164024/unrestricted/Indoor\_Navigation\_System\_for\_Handheld\_Devices.pdf. [Accessed 07 04 2021]. |
| [34] | Y. Zhou, H. Chen, Y. Huang, Y. Luo, Y. Zhang and X. Xie, “An Indoor Route Planning Method with Environment Awareness,” in *IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Valencia, 2018. |
| [35] | H.-y. Zhang, W.-m. Lin and A.-x. Chen, “Path Planning for the Mobile Robot: A Review,” *Symmetry in Engineering Sciences,* vol. 10, no. 10, p. 450, 2018. |
| [36] | J. Sun and X. Li, “Indoor Evacuation routes planning with a grid graph-based model,” in *19th International Conference on Geoinformatics*, Shanghai, 2011. |
| [37] | D. Zeinalipour-Yazti, C. Laoudias, K. Georgiou and G. Chatzimillioudis, “Internet-Based Indoor Navigation Services,” *IEEE Internet Computing,* vol. 21, no. 4, pp. 54-63, 2017. |
| [38] | R. Diouf, E. N. Sarr, O. Sall, B. Birregah, M. Bousso and S. N. Mbaye, “Web Scraping: State-of-the-Art and Areas of Application,” in *IEEE International Conference on Big Data*, Los Angeles, 2019. |
| [39] | JSoup, “jsoup Java HTML Parser, with the best of HTML5 DOM methods and CSS selectors.,” [Online]. Available: https://jsoup.org/. [Accessed 09 04 2021]. |
| [40] | T. Naeem, “PDF Data Scraping: Extracting Unstructured Data from PDFs Simplified,” 26 03 2021. [Online]. Available: https://www.astera.com/type/blog/pdf-scraping/. [Accessed 09 04 2021]. |
| [41] | PDFBox, “Apache PDFBox | A Java PDF Library,” 01 04 2021. [Online]. Available: https://pdfbox.apache.org/. [Accessed 09 04 2021]. |
| [42] | D. Zeinalipour-Yazti and C. Laoudias, “The anatomy of the anyplace indoor navigation service,” *SIGSPATIAL Special,* vol. 9, no. 2, pp. 3-10, 2017. |
| [43] | A. Morar, M. A. Balutoiu, A. Moldoveanu, F. Moldoveanu, A. Butean and V. Asavei, “Evaluation of the ARCore Indoor Localization Technology,” in *19th RoEduNet Conference: Networking in Education and Research (RoEduNet)*, Bucharest, 2020. |
| [44] | D. Cairns, “HardSys.ppt - HardSys.pdf,” 04 04 2006. [Online]. Available: http://www.cs.stir.ac.uk/~dec/teaching/CSC9T4/lectures/HardSys.pdf. [Accessed 23 04 2021]. |
| [45] | K. Sureshchandra and J. Shrinivasavadhani, “Moving from Waterfall to Agile,” in *Agile 2008 Conference*, Toronto, 2008. |
| [46] | M. Gannon, “An agile implementation of SCRUM,” in *2013 IEEE Aerospace Conference*, Big Sky, MT, USA, 2013. |
| [47] | D. R. Moogk, “Minimum Viable Product and the Importance of Experimentation in Technology Startups,” *Technology Innovation Management Review,* vol. 2, no. 3, pp. 23-26, 2012. |
| [48] | SQLite, “About SQLite,” [Online]. Available: https://www.sqlite.org/about.html. [Accessed 15 04 2021]. |
| [49] | Oracle, “Java Programming Language,” [Online]. Available: https://docs.oracle.com/javase/7/docs/technotes/guides/language/. [Accessed 15 04 2021]. |
| [50] | N. Walliman, Research Methods: The Basics: 2nd edition, Routledge, 2017. |
| [51] | M. Dixon-Woods, S. Agarwal, D. Jones, B. Young and A. Sutton, “Synthesising qualitative and quantitative evidence; A review of possible methods,” *Journal of Health Services Research & Policy,* vol. 10, no. 1, pp. 45-53, 2005. |
| [52] | J. Schoonenboom and R. B. Johnson, “How to Construct a Mixed Methods Research Design,” *KZfSS Kölner Zeitschrift für Soziologie und Sozialpsychologie,* vol. 69, no. 2, pp. 107-131, 2017. |
| [53] | Public Health England, “Mixed methods study - GOV.UK,” 02 06 2020. [Online]. Available: https://www.gov.uk/guidance/mixed-methods-study. [Accessed 23 04 2021]. |
| [54] | Anyplace, “AnyPlace | Indoor Information Service,” [Online]. Available: https://anyplace.cs.ucy.ac.cy/. [Accessed 15 04 2021]. |
| [55] | Navigine, “Precise indoor navigation and location tracking | Best indoor positioning system IPS by Navigine,” [Online]. Available: https://navigine.com/. [Accessed 21 04 2021]. |
| [56] | R. L. Mendez, “Indoor Real Time Navigation with SLAM on your Mobile - Graphics and Gaming blog - Graphics and Gaming - Arm Community,” 07 11 2018. [Online]. Available: https://community.arm.com/developer/tools-software/graphics/b/blog/posts/indoor-real-time-navigation-with-slam-on-your-mobile. [Accessed 21 04 2021]. |
| [57] | Raccoons, “Creating an ARCore powered indoor navigation application in Unity,” [Online]. Available: https://blog.raccoons.be/en/arcore-powered-indoor-navigation-unity. [Accessed 23 04 2021]. |
| [58] | R. A. Popa, H. Balakrishnan and A. J. Blumberg, “VPriv: Protecting Privacy in Location-Based Vehicular Services,” in *Proceedings of the 18th conference on USENIX security symposium*, Montreal, Canada, 2009. |
| [59] | C. S. Jensen, H. Lu and B. Yang, “Indoor - A New Data Management Frontier,” *IEEE Data Eng. Bull,* vol. 33, no. 2, pp. 12-17, 2010. |
| [60] | Rajkumar, “What Is Software Testing - Definition, Types, Methods, Approaches,” 09 01 2021. [Online]. Available: https://www.softwaretestingmaterial.com/software-testing/. [Accessed 16 04 2021]. |
| [61] | S. Avdoshin and E. Y. Pesotskaya, “Software risk management,” in *Software Engineering Conference in Russia (CEE-SECR)*, 7th Central and Eastern European, 2011. |
| [62] | Wrexham Glyndŵr University, “Course: Research Ethics,” 2020. [Online]. Available: https://moodle.glyndwr.ac.uk/course/view.php?id=26703. [Accessed 21 04 2021]. |
| [63] | G. L., “Applying for ethical approval for research: the main issues,” *Nursing Standard,* vol. 30, no. 20, pp. 40-44, 2016. |
| [64] | B. T. L and C. J. F, Principles of Biomedical Ethics, Oxford University Press, 2009. |
| [65] | K. Kelley, B. Clark, V. Brown and J. Sitzia, “Good practice in the conduct and reporting of survey research,” *International Journal for Quality in Health Care,* vol. 15, no. 3, pp. 261-266, 2003. |
| [66] | Fordham University, “sample\_consent\_for\_an\_internet\_survey\_1-22-15pdf.pdf,” 10 08 2015. [Online]. Available: https://www.fordham.edu/download/downloads/id/2430/sample\_consent\_for\_an\_internet\_survey\_1-22-15pdf.pdf. [Accessed 21 04 2021]. |
| [67] | Gov.uk, “Data protection - GOV.UK,” [Online]. Available: https://www.gov.uk/data-protection. [Accessed 21 04 2021]. |

# Figures

[Figure 1 - Gantt Project Chart 11](#_Toc70021138)

# Appendices

*Below I have included the ethical approval form for research projects in taught programmes at Wrexham Glyndwr University. Also included is my initial survey design which may change at a later date.*

## Appendix A – Ethical Approval Form

Also available on request

****

**Ethical approval of research projects in taught programmes**

There are 3 routes for review and approval:

1. RESC (Research Ethics Sub-Committee) - for staff and postgraduate research student proposals involving human subjects; all research involving animals, and all research requiring formal external approval [use the full RESC application form]
2. Staff and postgraduate research students Low Risk research [i.e. not covered by 1. above – use a Checklist and Cover Sheet form]
3. ***Research done by undergraduate and taught Masters students [use a Checklist and Cover Sheet form]***

**All proposals through all routes involve completing the relevant sections of the Checklist, to highlight any potential ethical risk factors.**

|  |  |  |  |
| --- | --- | --- | --- |
| Programme | MSc Computer Science | | |
| Module | COM738: Dissertation | | |
| Student Name | Connor Liam Laurence | Student ID | S15000373 |
| Research Project Title | Timetable Satnav | | |

I give approval for this research project to proceed, on the grounds that:

* it is consistent with the programme specification
* a suitable and sufficient risk assessment has been carried out
* the checklist has been fully completed
* it does not contain any ethical risk factors which may cause harm of any kind to research subjects, the researcher, the University or any other person or organisation

**AND/OR**

any risk factors have been clearly identified and appropriate measures put in place for their management and mitigation

* where relevant, appropriate and robust plans have been made to gain informed consent from prospective research subjects
* it is not required to be submitted for approval to the Research Ethics Sub-Committee

|  |  |  |  |
| --- | --- | --- | --- |
| Project Tutor Name |  | | |
| Signature |  | Date |  |

**Significant changes**

I approve the changes proposed by the student, on the grounds specified above.

|  |  |  |  |
| --- | --- | --- | --- |
| Project Tutor Name |  | | |
| Signature |  | Date |  |

**Notes:**

1. This form must be completed before primary data collection / experimental work begins.
2. The Checklist which follows must be fully completed.
3. The person approving the research must be satisfied that any ethical risk factors have been clearly identified and appropriate measures put in place for their management and mitigation.
4. This signed form should be filed with the student’s project proposal.
5. The University’s Code of Practice on Ethical Standards for Research is available at: <https://moodle.glyndwr.ac.uk/course/view.php?id=26703>

**Glyndŵr University - Checklist for ethical approval of a research project**

**Checklist 1 – to be completed for ALL proposals [answer ALL questions]**

|  |  |  |
| --- | --- | --- |
|  | **Yes** | **No** |
| 1. Does the research comply with the University’s Code of Practice on Ethical Standards for Research? [<https://moodle.glyndwr.ac.uk/course/view.php?id=26703>] | ✓ |  |
| 1. Does this research comply with the requirements of any relevant professional body’s code of conduct? [If Not Applicable’, mark ‘Yes’] | ✓ |  |
| 1. Has a suitable and sufficient risk assessment been carried out (including potential harm to the researcher)? |  |  |
| 1. Will the study require the co-operation of a ‘gatekeeper’ for initial permission / access to the people, animals, places, data, or other resources required for the research? |  | ✓ |
| 1. Does this research require the formal approval of an external body? |  | ✓ |
| 1. Could the research have an impact on people living or working in the immediate locality? |  | ✓ |
| 1. Will anyone other than the researcher (the applicant) and the research supervisor (if relevant) have access to the raw data produced by the research? |  | ✓ |
| 1. Is there a sponsor? |  | ✓ |
| 1. Is there a collaborating organisation? |  | ✓ |
| 1. Will any research be undertaken outside UK legal jurisdiction? |  | ✓ |
| 1. Will your research involve investigation of or engagement with terrorist or violent extremist groups? |  | ✓ |

**Does the proposed research:-**

|  |  |  |
| --- | --- | --- |
|  | **Yes** | **No** |
| Directly involve people? (go to Checklist 2) | ✓ |  |
| Directly involve animals or animal by-products? (go to Checklist 3) |  | ✓ |
| Have a potential impact on the environment? (go to Checklist 4) |  | ✓ |

|  |  |  |
| --- | --- | --- |
| **Checklist 2 Research directly involving people [answer ALL questions]** | **Yes** | **No** |
| 1. Will you use Social Media to interact with participants? |  | ✓ |
| 1. Does the study involve NHS patients, staff or premises? |  | ✓ |
| 1. Does the study involve participants who are particularly vulnerable (e.g. children, victims of crime, homeless, mental illness etc.)? Please read carefully the Code of Practice. |  | ✓ |
| 1. Does the study involve participants who would find it difficult to give informed consent (e.g. children, people with learning difficulties)? Please read carefully the Code of Practice. |  | ✓ |
| 1. Is a Disclosure and Barring Service (DBS) check required? |  | ✓ |
| 1. Will it be necessary for participants to take part in the study without their knowledge or consent at the time? (e.g. covert observation of people in non-public places) |  | ✓ |
| 1. Will the study require any deception of participants? |  | ✓ |
| 1. Will the study involve discussion of topics which the participants may find sensitive? (e.g. sexual activity, personal drug use, income etc.) |  | ✓ |
| 1. Are there cultural or religious issues associated with the research? |  | ✓ |
| 1. Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants? |  | ✓ |
| 1. Are drugs, placebos or other substances (e.g. food substances, vitamins, Chinese medicine) to be administered to the study participants? |  | ✓ |
| 1. Will the study involve invasive, intrusive or potentially harmful procedures of any kind? (e.g. Acupuncture, fitness testing) |  | ✓ |
| 1. Will blood or tissue samples be obtained from participants? |  | ✓ |
| 1. Does the proposed research involve human tissue or human embryos? |  | ✓ |
| 1. Is pain or more than mild discomfort to participants likely to result from the study? |  | ✓ |
| 1. Could the study induce psychological distress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life? |  | ✓ |
| 1. Will the study involve prolonged or repetitive testing? |  | ✓ |

|  |  |  |
| --- | --- | --- |
| **Checklist 3: Research directly involving animals [answer ALL questions]** | **Yes** | **No** |
| 1. Does the research involve any procedure that may have the potential effect of causing the animal(s) pain, suffering, distress or lasting harm? (regulated procedures under the terms of the Animals (Scientific Procedures) Act) |  |  |
| 1. Does the research involve a series of otherwise non-regulated procedures that together or cumulatively may cause that animal pain, suffering, distress or lasting harm? |  |  |
| 1. Does the research involve vertebrate animals or “Octopus Vulgaris” (protected animals under the terms of the Animals (Scientific Procedures) Act) |  |  |
| 1. Does the research involve using any animal by-products or tissue? |  |  |
| 1. Does the research involve any procedure or intervention on the animal(s) that is not part of its/their normal management practice? |  |  |
| 1. Does the research involve movement of animals from one place to another? |  |  |
| 1. Does the research involve animals in the wild? |  |  |

|  |  |  |
| --- | --- | --- |
| **Checklist 4: Research having a potential impact on the environment [answer ALL questions]** | **Yes** | **No** |
| 1. Do you have legal access / permission to work on the proposed site? |  |  |
| 1. Does the site have any legal designation (e.g. SSSI)? |  |  |
| 1. Could the research have an impact on the environment? (e.g. air / land / water contamination, damage to animal habitats)? |  |  |
| 1. Does the research involve working with any Genetically Modified Organisms? (e.g. GMOs in animal feeds)? |  |  |
| 1. Will you be importing plants, plant material, pests, soil or growing medium into the UK? |  |  |

## Appendix B – Initial Survey Design

