Analysis

1. Background to issues

Large buildings and indoor complexes (for example schools, universities, offices and airports) naturally have a large number of rooms and areas that people are expected to be able to get to. In the case of airports and similar establishments, the majority of people passing through do not use the building frequently, and as a result focus is placed on providing clear directions for people to travel efficiently. However, places such as schools, where most occupants are students that attend on a daily basis, typically have less focus on directions given that most students are familiar with where they should be at any particular time.

This makes it difficult for people who do not fall into this category, such as visitors and new students, to find their ways around; with my school in particular, a great deal of difficulty is experienced by incoming 4th Formers (new boys) in navigating the school in good time, with the additional disadvantage that taking too long to get to classes causes less learning and disciplinary sanctions. 4th Formers’ current provisions for acquiring directions lies upon checking a map provided by the school, which gives poor indication of a 4th Former’s current position or corresponding route to a room as well as requiring reliance on looking through the whole map to find a (potentially obscure) room. The only other opportunity is to ask other, senior students for directions; if not vague or unclear, these are often deliberately given incorrectly as a means of amusement.

As indicated above, this leads to several problems for many people, not only students. In the context of school, not only are new students learning less and receiving more punishment, but teachers and administrative staff also experience shorter lessons teaching less content and having to spend more time accommodating those who are behind in learning. In more general contexts, time spent travelling between places can evidently be critical depending on the context, for instance getting to the right gate in an airport in order to avoid missing a flight.

To this end, the goal of my project is to produce a mobile, smartphone-based indoor navigation system that will firstly provide a location search for rooms and areas within a building, as well as secondly providing path generation between two areas with a basis of graph traversal. In order to address the primary issue associated with not finding one’s way around a building, namely time lost, the system will have an emphasis on accessibility and clear user interface. The formal end-client will be Ms Caroline Gill, the 4th Form Undermaster (in charge of the year of new students), although the actual consumers/end users of the system will be people who use the large facilities (mostly new students and visitors to buildings). I will be using my school as a reference for research and as a model for any generic large building/complex.

1. Research

My research consisted of a series of interviews, a survey and miscellaneous research around navigation systems.

2.1 Interviews

I interviewed both the Undermaster and several 4th Formers in order to gain a holistic impression of the issues that getting lost produces, to both students and staff.

**Undermaster**

**Q. Do you find many fourth formers coming to you for help for directions?**

A. Quite a few, particularly at the beginning of the year. Some students ask for how to get to a room, though I find that directions usually aren’t the issue; most people manage to find the Geography Resource Centre or Room 105. It would be really useful if a pupil could match up a teacher or particular facilities with a room, as they have so much information to absorb in the first few weeks! I find that they know a general direction, but not the specific location.

**Q. Do people usually get a good idea of how to get around after a while in school?**

A. Yes, they usually know where they should be after a few weeks, although some of my tutees say that although they initially think they know where everything is, they may start another class later on in the year in a department they never knew existed, where they still don't know where to go. They don’t really get a perfect idea of where everything is until the year after.

**Q. Do you think that the majority of 4th Formers would be able to use a mobile system like this; that is, do most of them have smartphones/tablets etc. on which this could run?**

A. The school is beginning to acknowledge that as the case; all 4th Formers have to have access to a Wi-Fi enabled device (smartphone, tablet etc.).

**Q. Do you think that the school would like their building layout publicly available for all users of the building navigation system?**

A. I think the school would prefer it to be private in some way. Given that the school floor plans are kept relatively private by internal distribution (over intranet), I’d imagine that similarly restricting distribution would be sufficient.

During further discussion with the Undermaster, she raised the point that the school (or any organization) may not be willing to regularly (e.g. annually) update or re-create the map, and suggested that emphasis be placed on having map layout creation be as user-friendly as possible.

**Students**

The answers of multiple students were conflated into single answers for this document.

**Q. How late can you be as a result of getting lost?**

A. Since I only have five minutes to get to classes (assuming that I know how to get there), I’m usually at least a minute or two late when I don’t know how to get there. The teachers are empathetic at the start of term, but at the beginning there were one or two times when I went to the wrong side of the school to begin with and it took another five minutes to get to the right class again. I know some people who got detentions because of being late, but most people manage to mostly make it on time, especially after a few weeks.

**Q. What part of the school layout do you think makes navigating it especially difficult?**

A. Most rooms are fine to get to, especially if the general layout makes sense, like in the Science block; it’s just when the map isn’t clear about where a room is exactly within a rough space that I can’t find it. Even if I can get to roughly where the room is just fine, it’s hard to match up what the place looks like in real life to what the map shows.

**Q. Do you try to just memorise the whole map and school layout, or do just remember how to get to each room that you need to get to?**

A. I usually associate rooms I need to remember with recognizable or memorable places that are next to them, for example I remember that the language assistants’ rooms are next to Ms James’s room and that Mr Harrison’s room is near the Library.

**Q. Now that you’re familiar with where most rooms that you need to get to are, are there still any aspects of getting around that trouble you?**

A. I find it hard to match up the different floors with each other in terms of which side of one floor is above which side of the other. If I need to get to an Italian class on the second floor, I don’t know which side of the first floor I need to go to to go up a staircase.

2.2 Interview Analysis

From the Undermaster’s responses, I gathered that:

* As well as not knowing directions to and locations of individual rooms, students are also unaware of where individual teachers can be found (given that rooms are identified by number or name unrelated to occupying teacher), as well as where certain facilities are available.
  + To this end, the system should allow for rooms to have labels as part of metadata that contribute to search criteria when finding a room(‘s location), such as occupants.
* Students may not immediately retain perfect knowledge of where a room is, but otherwise in the long-term would not need to look up the location of a room again.
  + From this, I believe that implementing a search history, or alternatively a system optimised for calculating frequently queried routes, will not be necessary.
* As a platform for the front-end app for users to search locations, smartphones provide sufficient coverage for most students; an alternative, such as a web-app or desktop application should not be required.
* The school would require their layout to be distributed privately and to not be publicly available.
  + The system should therefore not require some kind of encryption, as the client is satisfied with ensuring privacy by distribution.
* Given the large number of rooms in a building, there exists a possibility that creating a map could become such a time-consuming task that consumers may not see benefit in using it in the first place, especially if facilities to modify a layout later are lacklustre.
  + As a result, emphasis should be placed on ensuring that, in addition to the front-end system for people needing to navigate, the ‘back-end’ layout entry/creation software should be optimised for user-friendliness, as well as providing facility to modify existing layouts without hassle.

From the students’ responses, I gathered that:

* The students’ margin of lateness is fairly low, and minimal time needs to be spent not travelling in the right direction.
  + To complement this, the user should be able to search a location within a period of time less than the margin of them being late otherwise, here stated as 1-2 minutes on average (taken as 90 seconds).
* The appearance of a room is often unclear when using the paper map as reference.
  + The system should therefore provide facility for each room to show what it would look like at the location, for instance by attaching a picture of the room to each room ‘node’ on the system layout.
* Associating rooms with nearby ‘landmark’ rooms helps in navigating to rooms.
  + To this end, room lying on the queried path should also be visible for inspection .
* The school layout between floors can be confusing for students.
  + To accommodate this, the front-end app should manage multiple floors or areas such that it is still clear how the floors are related in space.

2.3 Survey

The following survey was posited to the 4th form, receiving 79 responses:

1. So far, have you on occasion failed to find your way to particular rooms around the school?
   * Never: 11.4%
   * Not much: 62%
   * On several occasions: 26.6%
2. Of the times you have been lost, how often were you late to the class as a result of taking too long to get there?
   * Never: 10.1%
   * Sometimes: 41.8%
   * Most times: 38%
   * Always: 10.1%
3. Have you managed to memorise the locations of your routine weekly classes yet?
   * Yes: 70.9%
   * Mostly: 25.3%
   * Partially: 1.3%
   * No: 2.5%
4. Have you ever not been able to find something/someone on account of not knowing which rooms it/they are in (e.g. looking for a colour printer, but don't know which rooms have them)? If so, please specify an example (e.g. 'colour printer', teacher' etc.).

Teachers, societies, computers, printers, toilets.

1. Do you bring a smartphone to school?
   * Yes: 98.7%
   * No: 1.3%
2. If you answered ‘Yes’ to the above question, what type of smartphone do you use?
   * iPhone: 70.8%
   * Android: 26.6%
   * Other: 2.6%

Evidently, the claims of issue of this project are well-founded, with 89.9% of students having some issue with navigating the school. It is also well-supported that most students are familiar with their classrooms after only a few months, emphasising that this project is for short-term visitors of areas. The list of commonly queried facilities will be useful in (guidance for) creating layouts, and the fact that a reasonable portion of the 4th form use Android smartphones (the platform of my choice) implies that there is still a serviceable number that can use the app.

2.4 Miscellaneous research

* A project, done several years ago with the same premise as mine, had the primary criticism that the user interface was unclear and difficult to navigate, and otherwise impractical to use in a short period of time. This system should therefore focus on ease of user interaction as a priority, compared to speed of computation or other criteria.
* Google has created a similar system under the banner of Google Maps, termed ‘Indoor Maps’, that provides a similar service. However, it does not provide pathfinding or illustration of the room. It is also restricted in partners that can contribute layouts, and does not provide private layouts as required by the school, hence the lack of usage. I will therefore focus on these listed aspects of the system to differentiate it in function sufficiently enough from the Google system.

1. Justifications/Considerations
   1. **Usage of GPS**

Ideally, the user would be able to locate themselves via GPS on the layout, showing their position and demonstrating which directions to take (without having to search for their current location by entering the nearest room). However, according to the US Government, horizontal civilian GPS (Global Positioning System) positioning has a minimum accuracy of 7.8 metres (95% confidence interval)[[1]](#footnote-1), before even considering that it would have to be used indoors where signal would be considerably diminished (at worst travelling through several floors of concrete). Given that such distance is on the scale of distance between (several) rooms in indoor complexes, and that vertical positioning is even less accurate and so would be incapable of determining exact elevation, GPS would evidently be too inaccurate for use. An alternative is IPS (Indoor Positioning System), using indoor signals to triangulate position; however, despite the acronym, there is no singular standardized/inexpensive form of this, making implementation difficult. Wi-Fi signal strength triangulation is a possibility, but in addition to being non-standard and difficult to implement, this would require the back-end user to input the locations/details of each wireless access point across the entire building, which would take considerable effort from the user’s end. Therefore, the system will have to omit dynamic positioning such as GPS/IPS due to lack of favourable implementation.

* 1. **Route calculation – back-end or front-end**

Calculation of the optimal route between two nodes (rooms) will require a graph traversal algorithm, presumably Dijkstra’s algorithm or the Floyd-Warshall algorithm. In other navigation systems such as Google Maps, this is done via sending the initial and final locations to a back-end server which returns the optimal route (usually calculated using graph traversal and heuristics). This is typically required given the huge number of vertices and edges between nodes (areas). However, this obviously fails when no internet connection is present; such large buildings usually have poor mobile network carrier signal (for the reasons stated above), and Wi-Fi networks contained within usually need to serve a large number of people, leading to poor network/internet connection performance. Overall, internet connection in such large buildings can be limited; offline native graph traversal calculation would be preferable. Since the number of nodes (rooms) and edges (paths between rooms) are relatively low (not exceeding 200 or so), and since the worst order of performance complexity of a simple implementation of Dijkstra’s algorithm (simpler than the implementation used here) is *n2* (leading to maximum 40,000 operations), graph traversal of this scale would be achievable on smartphones, which typically have processors of above 1GHz processing speed (1 billion processor cycles per second), certainly not exceeding a few seconds in calculation time. For these reasons, the system should be able to perform pathfinding between rooms (as well as room lookup) locally and without internet connection (excluding downloading the layout in the first place).

* 1. **Timetable system**

Especially given that schools would be prime users of this project, a possible feature being considered was to implement a ‘timetable’ system where a user could define which room they would need to get to (and which one they were coming from) for a particular time period, for example at 2:15 get from Physics in room 102 to Chemistry in room 301; if the user opened the app at the particular time, it would instantly display where he needed to be and how to get there. While this would greatly reduce the time required to look up locations for each room in order to get directions, several aspects of research have implied that this would not be as useful as it appears. Firstly, this would require data entry from the user for inputting each timetable slot; using our school as a model, this would require 8 locations a day for 5 days per week, requiring the user to enter time slots and origin/final locations for 40 slots to accommodate everything; students may not wish to even use this feature if such additional effort is required. Secondly, as implied by the Undermaster’s interview/student survey, most boys become familiar with where they need to be and how to get there after a few weeks, especially if for a routine location like multiple classes per week. This means the repeated timetable would be effective for only a few iterations before becoming redundant, reducing its usefulness. For these reasons, it is evident that the timetable system does not serve enough purpose to be implemented, and thus will not be.

* 1. **Image storage**

In this system, the largest consumer of storage space on the user’s phone would be images for showing what each room looks like, as well as the layout backdrop itself. The two options available are to either retrieve the image from a server every time the user wishes to access it (reducing storage occupied) or store all images of the building along with the node (room) data on the phone. Although this would occupy more storage, consider the amount this would occupy; taking one image file to occupy 100KB at most, an upper limit of 200 images would occupy approximately 20MB, perfectly within the range of a small-sized app (the Facebook app on Android occupies between 200 and 300 MB of disk space). This would also comply with the ‘minimal internet connection required’ policy stated above. Therefore, the system will provide images for the user from the local storage as opposed to fetched dynamically from the back-end server.

**3.5 Miscellaneous**

* The system will be developed for Android operating systems, as it is the cheapest development option, the one I have most experience with, the one that is easiest to test and deploy, and one that should still have reasonable coverage across a number of students.
* Users would have to enter a particular ID to download the particular building layout they seek; even if this ID is not particularly long, another alternative ID entry method may be more convenient. One such method is use of a QR code, which can be scanned by a third-party application to direct the application to download the particular layout (with the benefit of better advertisement of the layout’s existence by promoting the QR code at the entrance of a building, for example. For this reason, users will be able to download a layout by scanning a QR code generated by the back-end layout submitter.

1. Function Specification

Secondary objectives that provide improved functionality but are otherwise non-essential (and have been deemed applicable in Justifications/Considerations) are marked in **bold**. Later on in the document, specification points will be referenced as ‘spec point X’, where X represents the number of the specification point.

1. Users will be able to download a building layout specific to a particular building, complete with details about each room and locations thereof, submitted by someone else through a submission platform. Users will be able to do this for multiple buildings/building layouts; for the sake of testing, at least five layouts should be able to be downloaded and stored without errors/issues arising.
2. The system will be developed for the Android (smartphone) platform.
3. A desktop data entry program should be available for creation of such layouts. For multiple floors of a building, users should be able to create room ‘nodes’ (imposed over a background image) and specify a room’s title, description, and associations, as well as connections with other nodes **and room image**.
4. The desktop data entry program should display one floor layout at a time (which can be changed to other floors), and should allow users to drag the view around and zoom in, as well as allowing the user to add/remove floors/rooms.
5. The layout in question to be retrieved and downloaded will either be specified by an ID entered directly into the app, or by scanning a QR code (using a third-party application) to specify which layout to download.
6. A search function will be provided for users to search for rooms using the room name as well as labels associated with the room (defined during entry of the layout). Labels will consist of terms that better define the room (for testing, samples of such terms would be whether the room has a printer, the room’s current occupant, and societies associated) and aid as additional search terms. Performing the search should display room properties (e.g. description, image) as well as location.

1. When found, rooms will be displayed with descriptions, associated labels, notes pertaining to the room, **and an image illustrating what the room looks like from the surrounding area**. The location of the room will also be illustrated by a ‘node’ being superimposed onto an image of the layout of the building, where the node lies on its respective location in the layout.
2. **The process of the system taking the user’s search query and performing a search should be carried out in less than three seconds.**
3. A function will be provided for users illustrating the path occupying the least distance between two nodes (rooms) that the user has entered. This will be represented as a coloured line passing through other nodes (rooms) (some potentially hidden, serving only as navigational midpoints), as well as arrows below/beneath nodes signifying whether the user should be ascending/descending floors at that node.
4. **The process of the system taking the user’s route query and generating/returning the optimal path should be carried out in less than five seconds.**
5. **The overall task of opening the app on a smartphone, navigating the user interface, entering a route or search query and receiving a response from the app should not take over 90 seconds overall.**
6. When generating a route to a room, ‘major’ areas being passed in reaching the room will also be highlighted in order to aid the user in understanding the location of the room.
7. Before the user has specified whether to make a search/route query, the system should display the layout backdrop of the (default) floor complete with all nodes (rooms) superimposed (and the option to change floor), with tapping each node akin to having searched for it; this will allow for the user to browse the layout before making a specific query.
8. The default layout view should have the following options:
   1. Users should be able to navigate the layout view by dragging the view around and zooming in and out (as with the desktop program), via touch gestures.
   2. It should be possible to re-centre the view to avoid getting ‘lost’ by excessive manipulation of the view.
   3. Users should have the option of hiding the representations of the nodes, leaving only the background layout image visible (for clarity).
9. **The space occupied by the system in the user’s device storage should not be excessive; to this end, the space occupied by the app when only my school’s layout has been downloaded should not exceed 50MB.**
10. **Besides retrieving/downloading the layout of each building, internet connection should not be required for usage of any aspect of the system; it should arise that, having downloaded a test layout, the app should perform perfectly as expected with no internet connection.**

1. http://www.gps.gov/systems/gps/performance/accuracy/ [↑](#footnote-ref-1)