A pervasive computing approach to mixed granularity indoor wayfinding

A Pervasive Computing Approach to Mixed Granularity Indoor Wayfinding

Daryl Feehely

A thesis submitted for the degree of Master of Science (MSc.) in Computer Science

Supervisor: Dr. Mikael Fernström

Interaction Design Centre
Department of Computer Science and Information Systems
Faculty of Science and Engineering
University of Limerick

Submitted to the University of Limerick, June 2014

A Pervasive Computing Approach to Mixed Granularity Indoor Wayfinding

Daryl Feehely

Abstract

Mystification and discovery are key components in the enjoyment and human experience of wayfinding and fundamental to its success. This thesis extrapolates this theory by applying it to indoor wayfinding, using a mixed granularity wayfinding solution within a pervasive computing context. To exemplify this a smartphone application was deployed with a mixed granularity mapping interface which allows users to view a floor map of a building containing navigation nodes and pathways as well as the coarsely granular location of points of interest with which users can explore the environment. Users may also access finely granular wayfinding information by scanning QR codes placed within the environment to pinpoint their location. The smartphone application was deployed among first year undergraduate students in the University of Limerick over a two year time period. Presented by this thesis is a mixed method quantitative deductive and inductive approach which employs a grounded theory strategy in answer to the research question. This mixed method approach consists of three experiments (one of which is the smartphone application), two deductive and one inductive combined with an inductive data analysis phase. Four research objectives overlap these experiments as a part of the research approach. The results are presented and show that a pervasive computing approach to mixed granularity indoor wayfinding can be successfully exemplified.

Declaration

I hereby certify that this thesis, which I now submit as fulfilment of the requirements for the award of Master of Science (MSc.) by research, is entirely my own work and that I have not used any other source apart from those cited within the thesis. Furthermore I declare that this work has not previously been submitted for any other academic award.

Signed Date

Daryl Feehely

Acknowledgements

First and foremost I would like to thank my supervisor Dr. Mikael Fernström for all his support, direction and encouragement during the production of this work.

Thank you to my examiners, Dr. Chris Exton and Dr. Ian Pitt.

To all of my collaborators in the University of Limerick, in particular Maura Murphy, Karen McGrath, Dr. Angélica Risquez and Professor Sarah Moore in the Centre for Teaching and Learning and Brian Considine, Gerard Hallinan, Pat McMahon, Donncha Corrigan and Derek Hogan in the Buildings and Estates Department, for all their help over the past three years. A special mention of thanks also to Aidan for hanging the QR code frames on campus.

To Professor Don Barry, President of the University of Limerick, for sparing his time to help promote the launch of the First Seven Weeks app and website.

To all of my friends and family who supported me during the production of this work, in particular Niall Kelly and Dr. Mark Glynn, who granted me an audience and provided valuable advice on many occasions.

Without the mentoring and encouragement of Dr. Brendan Cleary and Professor Eamonn Murphy, the willingness and ability to pursue this programme of study would not have come into existence, for which I am eternally grateful.

And finally, to my girlfriend Jenn Kirby, who provides constant support, empathy, advice, and motivation. Thank you for your ongoing enthusiasm and belief.

Table of Contents

List of Tables

List of Figures

Table of Appendices

List of Abbreviations

1. POI: Point of Interest
2. QR: Quick Response
3. CTL: Centre for Teaching and Learning
4. IDC: Interaction Design Centre
5. NFC: Near Field Communication
6. GSM: Global System for Mobile Communications
7. CMS: Content Management System
8. JSON: Javascript Object Notation
9. AR: Augmented Reality
10. SDK: Software Development Toolkit
11. OS: Operating System
12. LAMP: Linux, Apache, MySQL, PHP
13. EC2: Elastic Compute Cloud
14. SaaS: Software As A Service
15. GPS: Global Positioning System
16. PDR: Pedestrian Dead Reckoning
17. SLAM: Simultaneous Localisation and Mapping
18. LRS: Landmark Route Survey

1. Introduction

The proliferation of smartphone[1] devices has resulted in the device becoming a ubiquitous platform in modern pervasive computing (Cook, 2012). This thesis explores the use of a smartphone device in a pervasive computing context as a delivery platform for a mixed granularity indoor wayfinding solution. The wayfinding theories first proposed by Kevin Lynch (Lynch, 1960) are explored in a modern pervasive computing context using a smartphone application. The notion of enjoyable discovery through wayfinding by exploring unknown sections of an environment framed within a larger known context is implemented and evaluated using an alternative mapping solution, in the form of mixed granularity indoor wayfinding functionality, including a smartphone application deployed among first year students in the University of Limerick.

1.1.Smartphone Usage

High-volumes of smartphones are shipped worldwide each quarter. 179.7 million units in Q3 2012[2] were shipped, increasing to 227.8 million in Q4 2012, with a total of 722.4 million shipped in 2012. This leads to a 72% penetration rate[3] of smartphones in Ireland among 18-29 year olds as of 2012. A study conducted by (Paterson & Low, 2011) shows a rise in the use of smartphones by students in accessing library resources. A review performed by (Roach, 2010) looks at the

[1] A mobile phone that is able to perform many of the functions of a computer, typically having a relatively large screen and an operating system capable of running general-purpose applications. http://www.oxforddictionaries.com

[2] IDC Worldwide Mobile Phone Tracker, http://www.idc.com/getdoc.jsp?containerId=prUS23753512

[3] Mobile Planet Survey Result, http://www.thinkwithgoogle.com/mobileplanet

policies of many schools and universities in the United States and finds that the use of mobile devices is recommended tools for students. This thesis aims to contextualise and corroborate these statistics and positions by conducting a series of questionnaires on a subset of the University of Limerick student population, and in doing so, ascertain the current level of smartphone penetration and usage within that population.

1.2. The First Seven Weeks Programme

The First Seven Weeks Programme[4] is an orientation initiative, operated by the Centre for Teaching and Learning (CTL) at the University of Limerick, targeted at first year undergraduate students. It aims to provide support and orientation information during the first seven weeks of a new student's life at the University of Limerick. Information and resources delivered to students by the programme are themed for each week of the first semester and designed to focus the attention of the students on important orientation topics. A collaboration project was initiated between the Interaction Design Centre (IDC) in the department of Computer Science and Information Systems (CSIS) and the CTL, to allow the research contained in this thesis to be conducted. This collaboration allowed for the survey of students using two questionnaires, described in this thesis, to be conducted through the CTL. It also provided an opportunity to deliver the First Seven Weeks Programme information to students via new content delivery channels, namely a smartphone application and mobile website. The smartphone application is used as a delivery system for the mixed granularity indoor wayfinding solution presented as the primary research of

[4] First Seven Weeks Programme, CTL, UL http://www3.ul.ie/ctl/first-seven-weeks

this thesis. This thesis explores the design and implementation of this First Seven Weeks smartphone application and mobile website along with the analysis of its usage.

1.3. Student Questionnaires

Two questionnaires were distributed among the first year student body in the University of Limerick during the periods April/May 2012 and February 2013. The purpose of the first questionnaire is two-fold, firstly to ascertain the current landscape of smartphone usage among the student body (and by inference to corroborate the Mobile Planet smartphone ownership penetration rate of 72% among 18-30 year olds in 2012). Secondly, the questionnaire acts as a requirements analysis phase in the design and development of the First Seven Weeks smartphone application. The second questionnaire was distributed after the deployment of the First Seven Weeks smartphone application and its purpose is also two-fold. Firstly, it aims to compare and contrasts the results from the previous academic year's body of first year students. Secondly, the questionnaire aims to evaluate the effectiveness of the deployment of the smartphone application and mobile website, and by inference the mixed granularity indoor wayfinding solution included in the deployment of the smartphone application. The results of both surveys are detailed in Chapter 5 of this thesis and both questionnaires are described in section 3.4.

1.4. Smartphone Application & Mobile Website

Two scenarios were identified while ascertaining how users might access information delivered using smartphone technology. The first method is to download a smartphone application through which the information is delivered. The second method is to access a website in a mobile browser, termed a mobile website, to view the information. The latter method requires less commitment from the user, whereby the downloading of a smartphone application is not needed. Both methods, a smartphone application and a mobile website, are implemented to deliver the First Seven Weeks Programme information. In addition to this, the mobile website serves as an effective landing page for users when initially scanning one of many Quick Response (QR) codes placed in the buildings in the University of Limerick. This thesis describes the quantitative experiment carried out by creating and deploying the smartphone application and mobile website. The experiment is evaluated by analysing usage analytics and the results of the second student questionnaire.

1.5.Indoor Wayfinding

Wayfinding is defined as is *"a consistent use and organisation of definite sensory cues from the external environment"* (Lynch, 1960, p. 3). Wayfinding in a campus environment is a task undertaken daily by university students, whereby students access wayfinding information to orientate themselves and plot routes when travelling around campus. The process of wayfinding becomes particularly relevant in an indoor environment where students have the need to move between classrooms, lecture halls, laboratories and other rooms within one or many buildings. This thesis explores an alternative approach to indoor wayfinding by exemplifying a mixed granularity approach of defining and delivering the information used during wayfinding. This mixed granularity approach is implemented within the First Seven Weeks Android application and forms part of the quantitative experiment conducted in this thesis.

1.5.1. A Mixed Granularity Approach

While exploring a new environment via wayfinding, there is a balance to be found between the mystification or surprise felt in the exploration of an environment, and the anxiety felt by becoming lost in that environment. Kevin Lynch theorises that this balance can be found by defining an environment as an overall structured framework where *"the confusions must be small regions in a visible whole"* (Lynch, 1960, p. 6). The mixed granularity approach defined by this thesis creates a pervasive computing demonstrator of this in order to explore the application of this theory. The approach defines a coarsely granular indoor map structure, which depicts the location of rooms and points of interest (POI) between navigational juncture points, allowing the user to explore regions of the environment without being given the precise location of a POI. This coarse structure is set to scale within the precise frame of a building floor map which provides the necessary *"hint of connection"* (Lynch, 1960, p. 6). Further precision within this framework is provided by the placement of quick response (QR) codes within the environment. These QR codes are mapped to specific navigational junction points on each indoor floor map and allow the user to re-orient their position during wayfinding by scanning the QR code using the smartphone application, and thus restart their exploration process from a known point within *"the visible whole"* (Lynch, 1960, p. 6).

1.6. Data Analysis

This thesis presents the results of a series of analyses of quantitative data sources. Firstly, the data collected from the first student questionnaire is analysed to report on the current landscape of smartphone usage and to identify any statistically significant correlations. Secondly, the interaction and usage data captured from the Android application and mobile website during the deployment period is analysed to identify any patterns in behaviour. Thirdly, the data collected from the second student questionnaire is analysed to evaluate the deployment of the Android application and mobile website. These results are also comparatively analysed with the results of the first survey to identify any trends. The results of all these analyses are presented in Chapter 5.

1.7. Research Objectives

The research objectives of this thesis are as follows:

1. Perform a literature and state of art review of existing smartphone technology approaches used to implement indoor wayfinding solutions.
2. Investigate the current landscape of smartphone usage in accessing information in a university environment, by means of deductive quantitative experiments.
3. Investigate, implement and deliver a mixed granularity approach to indoor wayfinding in a pervasive computing context.
4. Evaluate this wayfinding solution through quantitative analysis of data from multiple sources.

1.7.1. Research Question

The following research question is explored by this thesis in fulfilment of the above research objectives.

1. Can a mixed granularity approach to indoor wayfinding be exemplified effectively in a pervasive computing context using a smartphone device?

1.8.Research Methodology

The research in this thesis follows a multi-method quantitative deductive and inductive approach, employing a grounded theory strategy, comprising of a series of questionnaires and observation experiments.

1.8.1. Research Approach

A multi-method approach is defined as the use of more than one data collection technique and corresponding analysis procedure or procedures (Saunders, et al., 2009, p. 152). In the case of this thesis, deductive and inductive quantitative approaches are used, whereby hypotheses are defined, tested and confirmed, which contribute to quantitative experiments, which result in the formulation of a theory based on the analysis of observational data captured from the quantitative experiments. The structure of this research approach can be seen in Figure 1.

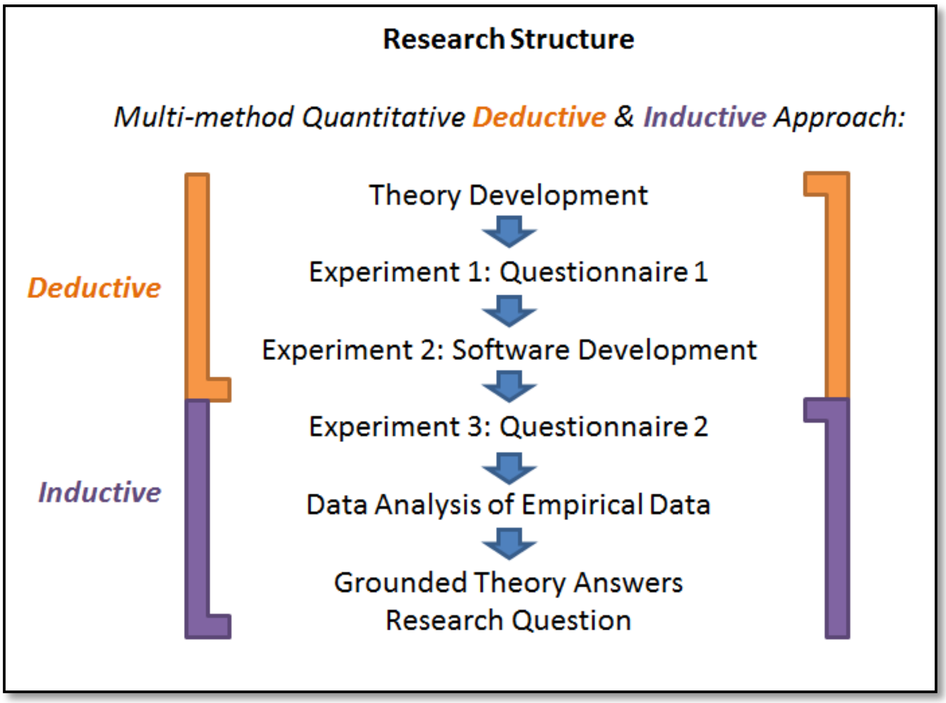


Figure 1. Research Structure

1.8.2. Research Strategy

A grounded theory strategy (defined as the discovery of theory from data (Glaser & Strauss, 1967, p. 1)) is used to induce a theory using data generated from a series of observations based on the deductive testing of hypotheses. Two questionnaires are used to ascertain the current situation with first year students in the University of Limerick as to how information is consumed using smartphone devices. Quantitative analysis is performed on the results of the questionnaire conducted. Smartphone software was developed and deployed in a pervasive computing context that allowed for the capture of usage information. This provides data about how and in which scenarios the software is used by the target cohort of users from their perspective.

1.8.3. Time Horizon

The time horizon of the research performed in this thesis is cross-sectional, in that a snap-shot of the first year student environment in the University of Limerick over a two year period is the basis for the observations performed.

1.8.4. Deductive Quantitative Experiments

A series of deductive quantitative experiments were carried out to investigate the current domain of smartphone usage in accessing information. The first deductive experiment is a student questionnaire which is used to observe the situation, leading to the analysis of the observational data captured. The following 2 hypotheses are formulated in order to be clarified by the analysis of the observation results.

1. Google Android is the best development platform on which to deploy the smartphone application because it is the most prevalent among first year students.

2. Mapping and directions are useful types of campus information to deliver using a smartphone device.

The clarification of these hypotheses contributes to the structure of the second deductive experiment, the software development of the smartphone application and mobile website. The observational data collected from the smartphone application and mobile website is analysed in an attempt to clarify the following hypotheses (which are also relevant to the third experiment):

1. Orientation information can be delivered and consumed effectively in a pervasive context using a smartphone device.
2. A mixed granularity approach to indoor wayfinding is effective in allowing users to navigate in an indoor environment.

The third deductive experiment conducted in this thesis is a second student questionnaire used to observe and compare change in the situation and inform on the effectiveness of the second experiment, the smartphone software deployment. The following hypothesis is defined, in addition to the previous two hypotheses defined during the second experiment which are also relevant, in order to be clarified by the analysis of the observation results.

1. Smartphone ownership among the first year student population is increasing.

1.8.5. Inductive Theory Definition

An inductive approach to theory development is defined as a research approach involving the development of a theory as a result of the observation of empirical data (Saunders, et al., 2009, p. 41). This thesis uses an inductive approach to develop a grounded theory, by observing the data collected and analysed from the three deductive experiments described in the previous section. This theory is used to inform on the exploration of the research question of this thesis as defined in Section 1.7.1.

1.9. Thesis Structure

Chapter 2 of this thesis presents a review of the current literature in the domain of indoor wayfinding in a pervasive computing context. Chapter 3 presents the main contributions of this thesis in the delivery of information using a smartphone application. Chapter 4 details the main contributions in relation to indoor wayfinding and the mixed granularity approach explored by this thesis. Chapter 5 describes the results of the contributions from exemplifications described in Chapters 3 and 4, and presents the results of the quantitative analyses performed. Finally, Chapter 6 presents the conclusions of this thesis and the suggestions for future work and research.

2. Indoor Wayfinding

This chapter describes the domain of indoor wayfinding in the context of mobile devices. The core principles of wayfinding are explored and numerous technologies and applications of indoor navigation solutions are described.

2.1. Wayfinding Principles

While Darken, et al. (2002) limit the definition of wayfinding to the process of building a cognitive map of the environment by whatever means without any movement, Allen (1999) describes wayfinding as the purposeful movement to a destination that cannot be perceived directly. In the context of this thesis wayfinding is treated as a combination of both definitions and describes the process of the creation of a cognitive map coupled with the use of the information and tools provided in navigating to a destination, either in-situ within the environment including movement or remotely before entering the environment. Three types of wayfinding tasks are defined, namely travel to a familiar destination; exploratory travel with the goal of returning to a familiar point of origin; and travel with the goal of reaching a novel destination (Ibid). All of these tasks are relevant when addressing wayfinding in an indoor environment and can also be considered as categories of wayfinding motivations or goals.

2.1.1. Cognitive Map and Emotional Security

A cognitive map, first coined by Tolman (1948), is a term used to describe the level of spatial information processing done by a user when mentally organising environmental spatial information. Lynch describes a cognitive map as mental picture or image and states that "*a good environment image gives its possessor an* *important sense of emotional security*" (Lynch, 1960, p. 4). He states that this emotional security is a factor in the successful process of wayfinding, so much so that any factor which impacts this emotional security should be limited so as to preserve the optimum conditions for successful creation of the mental image. In addition to this however, he describes how enjoyment is also integral to this emotional security, which is propagated by a sense of mystification during the exploration phases of wayfinding. A balance can be struck to allow the mystifying exploration to be experienced without damaging the emotional security of the user, and thus the successful creation of the cognitive map of the environment. To achieve this, it is proposed that "*confusion must be small regions in a visible whole*" (Lynch, 1960, p. 6), whereby the information delivered to aid in the process of wayfinding should be enough to describe the environment at a coarsely granular level but also allow exploration at a finely granular level. This balance is also described as *"serendipitous discovery"* (Darken, et al., 2002, p. 1) and stated as an important part of human navigation which reduces the experience of lost-ness during wayfinding. To achieve this balance it is proposed to make wayfinding tasks transparent and trivial while ensuring exploration and discovery are still possible. Studies conducted demonstrate that during wayfinding users do indeed find being in a void very uncomfortable and need regular assurance that they are not lost (Ibid).

2.1.2. Spatial Knowledge

The process of gathering spatial knowledge about an environment during the creation of a cognitive map is described by Darken (2002) with two possible collection methods reviewed. The first method, LRS (Landmark Route Survey) describes the knowledge collection process whereby a user becomes familiar with key landmarks in an environment in the first instance, followed by the familiarity of routes between landmarks which ultimately lead to an encompassing survey type spatial knowledge of the environment. The second method, Hierarchical, describes the process of building a detailed spatial knowledge of a local environment first in a short amount of time and then collecting more and more detail of surrounding remote areas over a longer period of time. The collection and development of spatial knowledge develops in parallel and is not restricted to any particular sequence or knowledge type such as landmarks, routes and survey knowledge (Montello & al., 2004). It is also proposed however that the spatial knowledge does begin with a skeleton central path (Kuipers, et al., 2003), which reinforces the importance of the physical path elements within an environment as described by Lynch (1960, p. 49). The manner in which a user gathers spatial information in the creation of a cognitive map and uses this map during the process of wayfinding is shown as model of navigation (Jul & Furnas, 1997). The model is an iterative goal and strategy based model, whereby the user defines a high level goal and implements iterative strategies to complete this goal. When the navigation is situated, the strategy is reactive based on the environmental information available to the user. When the navigation is plan-based, the strategy is survey knowledge based, allowing the user to generate a complete plan in achieving the goal prior to movement. A general framework of this model is defined as a continually cyclical process of action in the form of goal formation, strategy decision, data acquisition and scanning, followed by assessment in the formation of a concept model.

2.1.3. Wayfinding Strategies

The formation of strategies within the wayfinding model described by Jul & Furnas (1997) can vary depending on the environment. In the context of indoor wayfinding, three strategies are suggested which are put to the test in an experiment conducted within a complex multi-level building environment (Ho, et al., 2007). The first of the three strategies, central point strategy, describes the process of wayfinding using known areas such as landmarks and familiar paths irrespective of any route efficiencies. The second, direction strategy, describes the process of using direction as the primary decision point, irrespective of level changes and apparent route efficiencies and the third, floor strategy, describes the process of using survey knowledge of a given floor including route efficiencies for each floor. The experiment shows that the floor strategy is the best of the three because it allows users to reduce the navigation problem to a two dimensional problem space whereby the action and assessment loop is performed on each floor before moving up or down to the next floor in search of the destination. During the experiment a number of obstacles to successful wayfinding are also exposed, the main two being stairs and changes in layout per floor. Both result in an increase in spatial information processing. Wayfinding strategies within indoor environments can differ even when the destination point is the same (Mandel, 2011). The study conducted shows that of the participants observed, the majority navigate to their destination by the shortest route (53%) however the remainder do not. The author speculates that the reason for this may be due to the differing wayfinding goals and strategies of the users. Background knowledge of similar environments is shown to affect wayfinding strategies employed by users when wayfinding in an unfamiliar indoor environment (Frankenstein & al., 2012). The experiments conducted also show that in an unfamiliar indoor environment, corridors or halls with a longer line of sight distance and corridors with distinguishable landmarks are chosen more frequently as wayfinding strategies. Wider corridors are also chosen more frequently as a wayfinding strategy (Chang, 2009).

2.2. Technology Assisted Wayfinding

There are many examples of technology assisted wayfinding, some more recent examples of which are presented in this section. Technology assisted wayfinding is defined as the use of devices such as maps, signs, diagrams and direction giving machines which are sympathetic to the development of a mental image and that teach people to be well orientated (Lynch, 1960, p. 158). Lynch also states that people adjust to surroundings and extract structure from materials at hand and as a result, the success of wayfinding can be increased when the observer plays an active role in the process (Lynch, 1960, p. 43). The use of technology in wayfinding not only provides additional information to the user with which they can adjust to their surroundings, it also allows for the user to take an active role in the process while using the wayfinding information delivered by technology in the creation of a cognitive map. In this case, the term technology is meant to describe modern computer based technology, rather than the wider definition of technology under which the use of a paper map would be considered as technology assisted wayfinding.

2.2.1. Virtual Environments

One such technology is the use of a virtual representation of an environment, used to assist in the creation of a cognitive map and train the user before entering a real environment. Multiple studies have been conducted that test how a user navigates such a virtual environment and how effective a virtual environment is at training a user before entering the real environment (Darken, et al., 2002). In the examination of the process of cognitive map creation, the studies describe the use of a number of wayfinding techniques and the effect of these techniques on the process of wayfinding. The studies centre around the premise that information used to create a cognitive map is collected directly from the environment that is being navigated, be it virtual or real, as well as being taken from secondary aids such as maps and other tools. Within the virtual environment simulation, the study shows that the orientation of the environment or map is important in the context of the wayfinding and navigation. When the navigation is geo-centric and the map and/or environment are used as a reference without movement, north-up is the more efficient map orientation. When the navigation is ego-centric and the map and/or environment are used during movement, forward-up is the more efficient map orientation. The studies do show however that despite not being the more efficient during ego-centric navigation, north-up orientation is more preferred by the user. With regard to the creation of a virtual environment, with the intention of its' design being conducive to effective wayfinding, the elements first proposed by Lynch (1960) are referenced and used where appropriate. The use of these elements such as landmarks, paths and districts should be done so where relevant and that the identical use of all the elements may not be valid however (Darken, et al., 2002). When testing the effectiveness of a virtual environment being used to train a user prior to the entering of a real environment, the studies found that for periods of short exposure the use of a map as a training tool is more efficient than the use of a virtual environment. A training transfer that occurs using a virtual environment can surpass that of a map and a real environment, but only over long exposure periods. The process of indoor wayfinding in a real environment is compared against that within a virtual environment (Skorupka, 2009). The results of the comparison find that the length of time taken in a virtual environment is much longer than that in a real environment and that the paths yielded from both environments are different. Despite these differences, the qualitative aspects of the experiment reveal similar thought processes and cognitive rationale, such as environmental cue usage and search strategy adoption, used by the participants during wayfinding in both the real and virtual environments, further validating the effectiveness of the use of virtual environments as indoor wayfinding aids.

2.2.2. Tools and Techniques

The studies conducted by Darken (2002) also show that when constant reference points are used such as a grid overlay on a map or visible marker points within a virtual environment, the results of the wayfinding and navigation were both more successful and more enjoyable for the users. The studies also experimented with displaying the path already travelled by a user with the expectation that this technique would aid in the user retracing a path when orientation occurs. This expectation was disproven in the experiment, where users ignored the previous path indications and the technique eventually overloaded the virtual environment with redundant information. Route directions are evaluated and more specifically the quality of route directions and their component elements, such as landmarks listed and length, during the process of wayfinding for familiar and unfamiliar routes (Lovelace, et al., 1999). The results presented show that the completeness of route directions along with their length rated as higher quality. The placement of landmarks within the route directions, in particular the proximity of the landmark to navigation choice points also factor in the quality of the route directions. Landmarks not at choice points offer higher quality route directions for both familiar and unfamiliar environments whereas landmarks at choice points in familiar environments produce higher quality results.

2.2.3. Indoor Wayfinding Solutions

A number of different technologies and solutions exist in the area of indoor wayfinding, most of which aim to provide a precise or best estimation position of the user at any one time. The primary problem area with indoor navigation when compared to outdoor navigation is the degradation of satellite navigation system (e.g. GPS) signals indoors. With outdoor navigation and an unobstructed view of the sky, a strong satellite navigation system signal can be relied upon to deliver accurate positional information. Indoors however, a degraded GPS signal can introduce a high percentage error rate and cannot be solely relied upon to deliver accurate positional information. Many supplementary technologies and techniques have been developed to supplement, augment and/or replace the use of GPS for indoor localisation.

2.2.3.1. PDR and SLAM

A solution that combines inertial positioning data from an accelerometer, heading data from a digital compass, satellite navigation system positioning data and map matching algorithms to produce an indoor navigation solution is described (Gusenbauer, et al., 2010). The lack of an integrated gyroscope however leads to an accumulative heading error rate indoors and the solution also does not provide accurate altitude position data. The process of combining inertial data from an accelerometer, heading data from a digital compass and gyroscope data is known as PDR (Pedestrian Dead Reckoning). Many indoor navigation solutions implement

PDR because it allows the movement of the user to be tracked from a known starting position by counting the number of steps taken by the user and the direction in which the user travels. A PDR detection algorithm based on the zero point crossing method of footstep detection, whereby the number of times the accelerometer data reads as zero during movement is used to calculate the number of steps taken, produces an accuracy of at least 98% (Shin, et al., 2010). Attempts to use PDR combined with map matching to track the movements of the user in an indoor environment also exist (Pombinho, et al., 2010). Despite the addition of the gyroscope data in the PDR calculations and the refinement of the position data using map matching, the solution is not error free. Both Cho (2010) and Shin (2010) demonstrate solutions that attempt to further reduce the error rate of PDR by dynamically discovering the walking profile of the user which updates the calculated stride length accordingly resulting in reducing error rates with a 98% and 96% success rate respectively. Other methods of data collection in the calculation of PDR also exist (Chen & al., 2011) which describe the use of electromyography signal detection within leg muscles to calculate PDR distances. These examples demonstrate that PDR is a key technology component in addressing the problem of indoor localisation however more often than not cannot solely address the problem successfully. Simultaneous Localisation and Mapping (SLAM) is the process by which an entity dynamically builds a map of its environment while moving through it using data collected from a variety of sensors. The main application of SLAM is in the field of robotics and is generally implemented in real-time using PDR (Low, et al., 2009). In the context of indoor wayfinding however, SLAM can be used to build a map for the purpose of in-situ wayfinding or to generate a complete map for planning wayfinding. Such a solution is described (Shin, et al., 2012) which uses PDR and WiFi triangulation along with particle filter algorithms to implement SLAM within an Android smartphone application.

2.2.3.2. Hybrid Solutions

Along with Gusenbauer (2010), many other hybrid solutions exist which combine multiple indoor wayfinding, mapping and localisation technologies together in an attempt to solve the indoor wayfinding problem. The use of in-situ Bluetooth beacons is shown (Filonenko, et al., 2009) in combination with WiFi triangulation, accelerometer and digital compass data in producing an indoor navigation system. The solution measures signal strength from WiFi networks and the Bluetooth beacons to triangulate the position of the user, combined with PDR calculation based on the accelerometer and gyroscope data. While the system produces accurate results, the existence of an existing infrastructure, namely the Bluetooth beacons, is essential to the accuracy of the system. Solutions that combine acceleration magnitude monitoring based PDR, radio frequency identification and camera based SLAM (Simultaneous Localisation and Mapping) with various data filters and fuzzy logic algorithms exist (Koulouriotis, et al., 2011) which provide a self-sufficient indoor positioning system with built in redundancy. The system is again however not without error (2-3% error rate). Work is ongoing however in attempting to use mathematical modelling to further classify errors as alterations in the physical environment such a slope or ramp and compensate accordingly (Khalifa, 2013). Many other examples exist of solutions that use different combinations of technologies such as GPS and PDR (Zhang & Zhao, 2011), GPS, PDR and map matching (Akula, et al., 2011) and crowd-sourced collaborative PDR (Kloch, et al., 2011). A survey conducted (Fuchs, et al., 2011) presents further examples of hybrid indoor wayfinding solutions grouped by precision, deployability, complexity and relative costs. The results show that solutions using PDR as the main component are generally the most accurate but rely on the combination of multiple techniques. A hybrid solution deployed using an Android smartphone integrates acceleration magnitude recognition PDR and map matching with OpenStreetMap[5] (Smith & al, 2011) to enable cost-efficient collaborative deployment. Numerous commercial based products are also on the market that combines multiple technologies to deliver indoor wayfinding solutions. Two such solutions showcase SiRfusion by CSR which implements a hybrid solution deployed using a smartphone which combines satellite navigation system signals (GPS, Galileo, GLONASS and Compass), WiFi and cellular signal triangulation, PDR, cloud based processing and crowd sourced data mapping techniques to deliver a rapid and accurate indoor positioning system (GPSWorld, 2011). Addressing indoor wayfinding from an environment centric position rather than a user centric one, the Navizon I.T.S solution implements fixed node beacons which anonymously track the location of radio enabled devices within an indoor environment. Many hybrid solutions exist but none are perfect and the most appropriate solution chosen depends on the requirements of the scenario (Casas, et al., 2007).

2.2.3.3. Wayfinding and Mapping Interfaces

Numerous visualisation methods exist to display wayfinding and mapping information on the small screen of mobile devices. A study conducted compares the process of wayfinding on mobile devices using a generalised mapping interface and

---

[5] OpenStreetMap: http://www.openstreetmap.org

an aerial photography interface (Dillemuth, 2005). It is shown that the generalised mapping interface performs better than the aerial photography interface, with significantly shorter time to route completion and fewer zoom level changes. Experiments that test the preference of multiple mapping interface methods during wayfinding on a mobile device, specifically in the case of loss of localisation signal performance exist (Hochmair, 2008). Interface options such as 2D maps, 3D maps and text based wayfinding information are compared, in a graceful degradation of positional information scenario, a 2D map is found to be preferable by the user. A comparison study of indoor wayfinding using 3D models shows that a sparse 3D model results in more navigational accuracy than wireframe, high fidelity and low fidelity 3D indoor models (Li & Giudice, 2012). The use of cardinal directions such as North, North East, East etc. to describe routing information during wayfinding is found to be more efficient than the use of relative directions such as left, right, straight etc. (Shahrom, 2013).

Numerous graph based formats for structuring wayfinding information also exist. One such format is a vector based multi-layer map structure which categorises the nodes of a map graph structure based on four hierarchical levels; Building Level, Floor Level, Room Level and Sub-Room Level (Wang & al, 2007). A formal definition of a routing graph used to structure mapping information (Goetz & Zipf, 2011) includes node meta data such as rooms labels, accessibility constraints etc. The use of cardinal directions to encode the direction of linked nodes in a mapping graph also exists (Osborn & Hinze, 2013).

2.2.3.4. Quick Response Codes

Quick Response (QR) codes are matrix based two dimensional barcodes used to encode information, as defined in the ISO/ISEC 18004:2006[6] standard. In a modern pervasive computing context, QR codes are often used to encode website URL information which can be scanned using a QR code scanner on a smartphone. Indoor wayfinding solutions exist that leverage this functionality to provide in-situ contextual information to users during wayfinding. An example of this wayfinding information delivery exists (Mulloni & al., 2009), although this solution does not use actual QR codes but uses similar matrix based markers which are interpreted and parsed by a user's camera phone to display positional information. An indoor wayfinding solution is presented that utilises the placement of QR codes at points within an indoor environment which, when scanned, provide positional information (Lyardet, et al., 2008). The solution presented however is implemented on camera phone devices and is a pre-smartphone era exemplification. A solution exists which uses QR codes printed on posters to allow the user to download a map of the location using a smartphone and also display the user's current location on the map (Serra, et al., 2010).

2.2.3.5. Augmented Reality

Augmented reality (AR) is the term used to describe the process of overlaying environment information onto a video feed of the environment, for example the display of information on a smartphone device overlaid on the view as seen from the

---

[6] ISO/ISEC 18004:2006 – Automatic identification and data capture techniques: http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=43655

video camera of the smartphone. The use of AR to aid in the process of wayfinding indoor is described (Ahn & Han, 2011) whereby the use of PDR and AR result in a smartphone application that aids users in wayfinding to an exit in the event of an emergency. The system uses room number plaques within the environment as image markers and calculates the position of the user when these image markers are encountered. Routing information is then overlaid on screen, such as directional arrows and 2D maps of the environment, to aid the user in wayfinding to the exit. More encompassing examples of AR navigation are presented by Hile and Borriello (2007) and Kim and Jun (2008). Both solutions detail the use of image recognition techniques to identify the structure of an indoor corridor, match this to an existing building structure database and provide positional information. This information is then overlaid on the screen of the mobile device with directional routing arrows to assist in wayfinding to the desired destination.

2.3.Summary

This chapter reviews literature that details the core principles of wayfinding including how spatial knowledge is collected, categorised and utilised within the cognitive map of a person in the process of wayfinding. The chapter continues by presenting a state of the art review of various technologies used to assist the user during wayfinding, with specific attention paid to the indoor wayfinding. Key points presented by this literature review show that for short periods of exposure a map is the most efficient wayfinding aid and that only the most essential wayfinding information, such as a 2D map or a sparse 3D map, is preferred by the user. Examples of how wayfinding information is structured, formatted and displayed are also presented. The literature also highlights the importance of guarding the emotional security of the user during the creation of a cognitive map and wayfinding by preserving the experience of exploration and discovery while at the same time reducing the sense of lost-ness. Many examples of indoor wayfinding solutions using mobile technology are presented, most of which are hybrid solutions that utilise PDR and a combination of other localisation technologies.

3. Android Smartphone Application & Mobile Website

This chapter describes the main contributions of this thesis in the design, implementation and deployment of an Android smartphone application and mobile website. This deployment, and the analysis and evaluation of this software, form one of the deductive observational experiments included in the multi-method research approach taken by this thesis, as described in section 1.8. The other deductive observational experiments performed by this thesis are two student questionnaires, which form part of the requirement analysis and evaluation of the software deployment respectively, which are also described in this chapter.

3.1. A Pervasive Computing Approach

Pervasive computing, also referred to as ubiquitous computing, is defined by IBM as *"Convenient access, through a new class of applications, to relevant information with the ability to easily take action on it when and where you need to"* (Uwe Hansmann, 2001, p. 11). The four principles of pervasive computing; Decentralisation, Diversification, Connectivity and Simplicity (Uwe Hansmann, 2001) describe the heterogeneous, cooperative, optimised and convenient landscape of pervasive computing devices and applications and all four hold true when examined in the context of the current smartphone device and application domain. A smartphone application can be defined as an intervention into the reality of the user, with the purpose of delivering additional information into the users' reality. The concept, architecture and standard features of a smartphone device and application satisfy all four pervasive computing principles. A smartphone is a decentralised computing device that communicates with other devices using the many wireless data transfer protocols available. The early concepts of inch scale tab computing devices with wireless network connectivity and the ability to augment existing computer infrastructures to create an embodied virtuality for the user (Weiser, 1991) have now become a pervasive reality with the invention of smartphones. Smartphones are diverse devices in the environment of computing devices which are designed, first and foremost, as devices to be used to perform telecommunications functions and to access information in a mobile context. Smartphones have a high degree of connectivity whereby other devices can exchange information with them via short range wireless data transfer protocols such as Bluetooth and NFC. Smartphone devices also connect to long range wireless networks such as GSM for telephony and 3G for mobile data access. Finally, a smartphone device is simple in the context of its inner operation being hidden from end users. It is designed to provide a specific user experience through the seamless integration of hardware and software in the form of its operating system (OS) and applications that run on its OS. The smartphone is described as *"ushering in the real age of ubiquitous computing"* (Abowd, 2005) and it is now accepted that smartphones are portable devices that are part of the current pervasive computing domain (Cook, 2012). This thesis uses a smartphone device to exemplify a pervasive computing approach to a mixed granularity indoor wayfinding solution. A smartphone application was developed and deployed as an intervention into the reality of the user, with the purpose in this case of delivering additional information into the users' act of wayfinding in an indoor environment. This thesis takes advantage of the inherent pervasive computing properties of the smartphone platform to firstly develop a smartphone application within a defined smartphone development framework (Google Android[7]), and secondly to deploy this platform to a mainstream dissemination network (Google Play Store[8]). This deployment is intended to integrate seamlessly into the reality of the user via their smartphone, allowing the user to interact with, and consume the information delivered by the mixed granularity wayfinding approach exemplified by this thesis.

3.2. Collaborative Approach

The vehicle that enabled the exploration of the mixed granularity approach to indoor wayfinding in this thesis was the collaboration between the Interaction Design Centre (IDC) and the Centre for Teaching and Learning (CTL) in the University of Limerick. This collaboration was focused on improving the First Seven Weeks Programme, which is an orientation initiative, delivered by the CTL to new first year students. The programme aims to aid the transition of students from second level education to third level education by providing relevant targeted orientation information. Improvement to the First Seven Weeks programme was undertaken by investigating the feasibility of delivering the programme information to students using a smartphone application, and subsequently developing and deploying this smartphone application. The feasibility study took the form of a questionnaire circulated to all first year students in the University of Limerick. The delivery of the information took the form of a deployment of an Android smartphone applications and mobile website. The effectiveness of the deployment was evaluated using a

[7] Android Smartphone Development Platform: http://developer.android.com/about/index.html

[8] Google Play Store: http://play.google.com

follow-up questionnaire, which also acted as a comparative source of quantitative data to the information collected by the first questionnaire.

3.3. First Seven Weeks Programme

The information delivered by the First Seven Weeks programme is designed to aid new students in orienting themselves into the life of pursuing a third level education in a university. The programme categorises the orientation information into seven weekly themes, designed to make students aware of learning and lifestyle information and supports available on campus at the University of Limerick during their first semester. The programme also aims to teach a number of skills that are of benefit to third level students in the areas of studying, planning and civic engagement. The programme is based on research conducted that identifies a correlation between the engagement of a new student in the first six weeks of their first semester in university and the reduction in the dropout rate of first year students (Tinto, 1988). The themes used by the programme are Week 1: Welcome, Settling In, Finding Your Way Around, Week 2: Study Skills and Time Management, Week 3: Health and Wellbeing, Week 4: Meet Your Advisor, Week 5: Learner Support Centres, Week 6: Career, Civic Engagement and Volunteering Awareness, and Week 7: Critical Thinking and Longer Term Planning. The programme also delivers ancillary campus information each year to accompany the main weekly themes in the form of photos, videos and documents relevant to each weekly theme. The smartphone application and mobile website developed as part of this thesis packages and delivers all of this information. The smartphone application also includes the implementation of the mixed granularity indoor wayfinding as defined by this thesis. As one of the goals of the First Seven Weeks Programme is to help students orientate themselves on campus, the functionality delivered by this thesis' implementation of a mixed granularity wayfinding solution aligns naturally with the goals of the First Seven Weeks Programme.

3.4. Smartphone Questionnaires

3.4.1. The First Questionnaire

The first of two questionnaires was developed to investigate the current landscape of smartphone usage among first year students. The questionnaire was conducted online over the period of April to June 2012 among all first year students in the University of Limerick. The first questionnaire distributed is included in Appendix A.1 along with the research ethics information and consent sheet in Appendix A.2 which accompanied the questionnaire. The questionnaire comprises a list of multiple choice and 5 point Likert-type scale (Likert, 1932) questions used to ascertain and measure different aspects of smartphone usage. The order of the Likert scale options are counterbalanced to reduce the impact of familiarity the participants may have with the scale options. Areas investigated using these questions include the rate of smartphone penetration, the breakdown of smartphone manufacturer ownership, the proliferation of different smartphone operating system versions, the level of pre-pay versus post-pay contracts, intentions of participants on getting a smartphone within the next year, and the breakdown of ownership by the participant's study discipline. Participants with smartphones are asked about how often they use their smartphones for different activities, and how important these activities are to them. Participants without smartphones, but who intend getting a smartphone, are also asked to rate how important each activity is to them. The activities measured are; Accessing Social Networks, Using Apps to Access Information, Performing Web Searches, Gaming, Watching Videos, Listening to Audio/Radio, Taking Photos, Map Navigation & Directions, Downloading & Installing Apps, and Web Browsing. Participants are asked to rate how often they access a University Website, Notice Boards, Social Networks, Contact with Student Union, First Seven Weeks Programme – online, First Seven Weeks Programme – offline, and Word of Mouth as sources of campus information. The importance to participants of each of these campus information sources is also measured. Using a 5 point Likert scale each participant rates how likely they would be to use a list of features on a university smartphone application if one existed. These features include; Campus Directions, Facilities Guidance & Information, Offer & Deals Information, Entertainment & Social Information, Lifestyle Guidance & Information, Academic Guidance & Information, Career Guidance & Information, and Skills Guidance & Information.

The first questionnaire is the first deductive experiment contained in the multi-method research strategy of this thesis. With particular emphasis on stages 4 and 5 of the sequential stages of deductive research progression (Robson, 2002), the outcomes of the questionnaire are examined and the theory is modified if necessary in light of the findings. In the case of this thesis, the sub-hypotheses described in section 1.8.4 of this thesis, regarding the selection of the Android smartphone platform and the usefulness of mapping & directions campus information, are directly tested by the findings of the first questionnaire.

3.4.2. The Second Questionnaire

A second questionnaire was developed with two purposes in mind. Firstly, the questionnaire investigates the same areas as the first questionnaire, allowing for comparative analysis of the landscape of smartphone usage among first year students across a two year period. Secondly, the questionnaire includes questions designed to evaluate the deployment of the First Seven Weeks Android application and mobile website. The second questionnaire distributed is included in Appendix A.4 along with the research ethics information and consent sheet in Appendix A.5 which accompanied the questionnaire. Areas in which the effectiveness of the Android application and mobile website are measured include; the level of awareness of the application and mobile website among participants, the frequency at which participants scanned the QR codes with their smartphone, not using the application to view the mobile website, and using the application to view their location on map, and the frequency at which participants used the features available to access campus information. These features include accessing information on weekly theme, weekly photos and videos, weekly documents, floor maps of the main building and other buildings, and accessing the First Seven Weeks Programme Facebook page[9].

The second questionnaire is the third deductive experiment contained within the multi-method research strategy of this thesis. The sub-hypotheses described in section 1.8.4 of this thesis, regarding the delivery of wayfinding information using smartphone devices and the level of smartphone ownership, are directly tested by the findings of the second questionnaire.

3.5. First Seven Weeks Android Application & Mobile Website

A goal of the collaboration process between the CTL and IDC was to develop a smartphone application for the First Seven Weeks Programme. The purpose of this

---

[9] First Seven Weeks Facebook page: http://www.facebook.com/first7weeks

smartphone application was to deliver the programme's information to students while also providing an environment for deductive observational research experiment to be carried out as part of this thesis. This observational research focuses on evaluation of a smartphone application designed as an intervention into the reality of the user with the purpose of delivering an implementation of a mixed granularity approach to indoor wayfinding as described in Chapter 4. During the deductive research approach taken by the first questionnaire, the Android smartphone development platform was hypothesised and confirmed as the most prolific of smartphone operating systems among the target student audience. Results that show the breakdown of smartphone operating systems and confirm this hypothesis are presented in Chapter 5. A majority of smartphone users reported that they had Android-based devices. This was not the only reason why it was chosen as the platform on which to build the First Seven Weeks smartphone application. The shorter approval time of applications submitted to the Google Play Store, advertised by Google as a few hours[10], coupled with the less stringent approval process and the $25 developer registration fee [11] also contributed to the decision. The shorter approval time allowed for more flexibility in the deployment timeline of the application and flexibility in developing updates of the application. The less stringent approval process allowed for the application to be deployed with the Faculty of Science and Engineering Ethical Committee disclaimer as described in section 3.5.3.3, along with the facility to capture and transmit user interaction data from

---

[10] http://developer.android.com/distribute/googleplay/publish/preparing.html#final-checks

[11] $25 Registration Fee: http://developer.android.com/distribute/googleplay/publish/register.html

those users who opted to become participants of the research project. The analysis and results of this deductive observational experiment are described in Chapter 5.

Even though the results of the first questionnaire (which are presented in full in Chapter 5) show that majority of smartphones owned by students were Android smartphones (46%), a smaller but yet considerable amount of smartphones owned were Apple smartphones (32%). As a result, a mobile website was also developed in order to deliver the programme information to the smaller cohort of students using Apple iPhones. An added advantage of developing a mobile website is that it acted as a landing area that presented a page of information about the First Seven Weeks Programme when a user scanned one of the QR codes placed in the undergraduate buildings on campus in the University of Limerick. This page of information also contained a link to download the First Seven Weeks Android Application[12] directly from the Google Play Store.

3.5.1. Architecture

The architecture of the smartphone application and mobile website comprise two distinct systems, the Android application which was deployed on the smartphone device, and the Drupal[13] content management system (CMS) which was used to deliver the responsive mobile website and to manage and update the content of the Android application. The relationship between these systems is shown in Figure 2.

---

[12] First Seven Weeks Android App: https://play.google.com/store/apps/details?id=com.ul.idc.F7W

[13] Drupal CMS: http://www.drupal.org

The Drupal CMS was deployed in a cloud hosting environment using an Amazon AWS[14] micro instance cloud computing server.

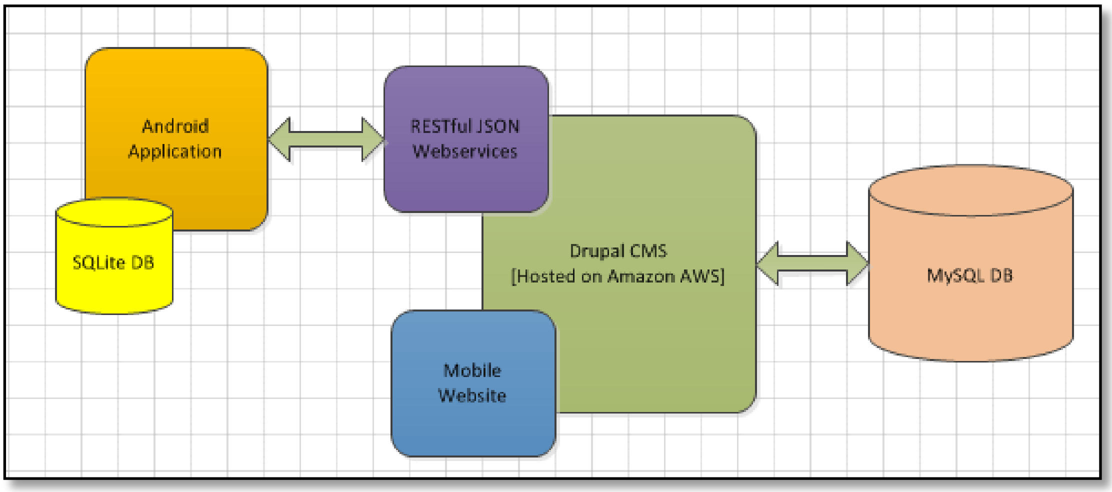


Figure 2. Solution Architecture

The use of QR codes within the deployed solution is twofold; firstly the user has the ability of accessing the mobile website by scanning any of the QR placed on campus. Once scanned using a barcode scanner application, the QR code links the user to a landing page on the mobile website which contains links to the First Seven Weeks Programme information, as well as a link to download the smartphone application. Secondly, when a QR code is scanned from within the First Seven Weeks Android application, the location of the QR code, and thus the user, is displayed on an indoor floor map. The purpose of this feature is to allow the users to re-orient themselves during the process of exploratory wayfinding, as described in Chapter 4.

---

[14] Amazon Web Services Cloud Computing: http://aws.amazon.com/

The Android application uses a variety of data sources to deliver the First Seven Weeks Programme information, and to deliver the mixed granularity indoor wayfinding solution included in the mapping feature of the application. These data sources include a SQLite database[15] used to store the textual First Seven Programme weekly information as described in section 4.4, the structure of the menu system used in the application, and the list of buildings along with the number of floors in each building. The application also uses the Android assets framework to store the floor map definition files, the list of QR codes deployed and the nodes to which they are assigned, and the images used within the menu system of the application. All of these data sources can be updated centrally using the Drupal CMS and updates are delivered to the application using Javascript Object Notation (JSON)[16] via RESTful web service calls.

3.5.2. Requirements

Throughout the development of the smartphone application and mobile website, a number of requirements were iteratively identified, evaluated and implemented. This section describes these requirements and how they impact on the deployed solution.

3.5.2.1. Deployment Platform

The first requirement in delivering information via a smartphone application is to identify the most relevant deployment platform. The first questionnaire, as described in section 4.4.1, yielded a positive result in proving the hypothesis described in

---

[15] SQLite Database: http://www.sqlite.org/

[16] Javascript Object Notation (JSON): http://www.json.org/

section 1.8.4. As a result, the Android smartphone platform was selected as the most relevant deployment platform because it was the most prolific among the target cohort of first year students.

3.5.2.2. Content Management System (CMS)

The next requirement addressed is that of the identification of a CMS to deliver the responsive mobile website and also to allow the maintenance of the content for both the Android application and mobile website. The open-source PHP based Drupal CMS was identified as an appropriate system to deliver this mobile website. Drupal is a template based system, allowing a custom mobile web template to be developed easily. Drupal also offers additional and custom functionality to be configured and/or developed using its module system. This ability allowed the deployment to include additional JSON RESTful webservice functionality, whereby content from the CMS can be requested in JSON format, allowing for more streamlined data transfer to and from the Android application. The updating of content within the Android application was accomplished using JSON webservice calls to the Drupal CMS. This allowed updates to the First Seven Weeks programme weekly information and updates to the floor map definitions to be downloaded by the Android application when the smartphone was connected to the internet. This eliminated the need to publish a new version of the Android application to the Google Play store when updates needed to be made to the content of the Android application, hence potentially improving maintainability.

3.5.2.3. Responsive Design

A requirement of the mobile website was that it be viewable consistently on as many mobile devices as possible. This was achieved by using the Drupal Omega[17] theme, which is a responsive web theme based on the *960 grid system*[18]. The mobile website included in the deployment was a modified version of this Omega theme which included all the First Seven Weeks programme weekly information. Part of the responsive design of the mobile website included the need for images to be displayed at the correct size and scale relevant to the size of the screen display. This functionality was achieved using the Drupal Adaptive Images[19] module which delivers the correct size image based on the client screen resolution.

3.5.2.4. Cloud Hosting

The potential target cohort of first year students in the University of Limerick is approximately two to three thousand students each year. Approximately eight hundred and fifty of these students have an Android smartphone based on the results of the first questionnaire and as a result could potentially download the Android application. Also, because the First Seven Weeks programme is highly active in the first seven weeks of the first semester, a potential peak of data traffic in the first few weeks of deployment is likely. As a result, a flexible hosting environment was identified as a high priority requirement of the deployment. The ability of cloud hosting to flexibly scale depending on the resources needed made it likely to be

---

[17] Omega Theme: http://drupal.org/project/omega

[18] 960 Grid System: http://960.gs

[19] Adaptive Images Module: http://drupal.org/project/adaptive_image

appropriate for the deployment of the Drupal CMS, which not only delivered the responsive mobile website but also processed any JSON update requests from any of the Android applications in use. A micro-instance on an Amazon AWS Linux server was selected as the ideal cloud hosting platform because of the flexibility offered by Amazon AWS in provisioning more resources if and when they are needed.

3.5.2.5. Quick Response (QR) Codes

The use of QR codes requires that the smartphone application include scanning functionality. This is achieved using the ZXing[20] open source barcode decoder library. A feature of the mapping interface of the Android application allowed the user to scan a QR code to see the position of the QR code on a floor map, and thus pinpoint their current location. This process is described in detail in the next chapter.

3.5.2.6. Augmented Reality (AR)

Initially it was intended that the Android application would also include Augmented Reality (AR) technology to portray outdoor wayfinding information to the user using the camera overlay method of information display used with AR. Some prototype functionality was developed using the MetaIO[21] Software Development Toolkit (SDK). This functionality is not included in the final deployment of the Android application because the priority of this thesis was restructured to focus on indoor wayfinding and the implementation of the mixed granularity approach described in the next chapter.

---

[20] ZXing Barcode Decoder: http://zxing.org

[21] MetaIO SDK: http://www.metaio.com/products/sdk/

3.5.2.7. Usage Data

In order to satisfy the requirement that this deployment acts as a deductive observational experiment, detailed usage data had to be captured from both the Android application and mobile website. This was accomplished using two methods, with Google Analytics and with purpose built logging functionality within the application. Google Analytics was used to anonymously measure the traffic usage for both the Android application and mobile website. The purpose built logging functionality was needed because the non-contextual anonymous transactional methods that Google Analytics uses to capture and transmit data does not sufficiently profile the sequential nature of the interactions that a particular user may have with the Android application, and in particular with the mapping features. The logging functionality captured data based on the Android device identification number of a particular user's smartphone. This allowed for the analysis of sequential patterns of user interaction, as described in Chapter 5. This Android identification number was not linked to any other personal information that could be used to identify the user. In order to capture information using the purpose built logging functionality, consent was needed from the user and the facility that allowed them to opt-in or out of the research project was also needed. This consent was implemented using a form that appeared when the application was opened for the first time. This consent form displayed a research disclaimer to the user and gave the option to the user to opt-in or opt-out. This consent form could also be accessed from the menu system of the application at any time by the user. Only data from users that gave their consent via this form was analysed in the results. A screenshot of this consent form can be seen in Figure 72 in Appendix B.

3.5.3. Specification, Design & Implementation

During the design phase of the Android application and mobile website the specification of a number of features were defined, based on the list of requirements identified coupled with the iterative design of the application and website. An iterative review process led to most of these features being implemented in the final deployment. This section describes these feature specifications and designs, describes the implementation of these features and details how each feature is developed in adherence to usability principles.

3.5.3.1. Feature List

Based on the requirements, the following is the feature list defined as included in the deployment of the Android application and Drupal mobile website; Splash screen including relevant logos, Disclaimer and consent form, Hierarchical menu system, Display of First Seven Weeks Programme text, images, video and document weekly content, QR code scanning capabilities, Usage data collection and transmission, Content update functionality using JSON requests, Augmented Reality information display functionality; Responsive delivery of a mobile website hosted in a cloud environment, Outdoor Campus map and Mixed granularity indoor wayfinding functionality. The design and implementation of each of these features is described in the remainder of this chapter, apart from the mixed granularity indoor wayfinding functionality. A detailed description of the inception, design, specification and implementation of the mixed granularity indoor wayfinding functionality is described in the next chapter. The Augmented Reality and Outdoor Campus Map features were removed from the feature list during the development of the Android application following a review of the direction of this thesis and the decision to focus on indoor wayfinding. Once an initial feature list had been defined, the structure of the Android application and website was developed using a series of sketches, wire frames and mock-ups.

3.5.3.2. A Design Process; Sketches, Wire Frames & Mock-ups

The process of designing the Android application interface started with some initial sketches of the home screen which can be seen in Figure 3. The purpose of these sketches was to define the high level outline of each screen of the application, as well as the relationships in navigation between each screen.

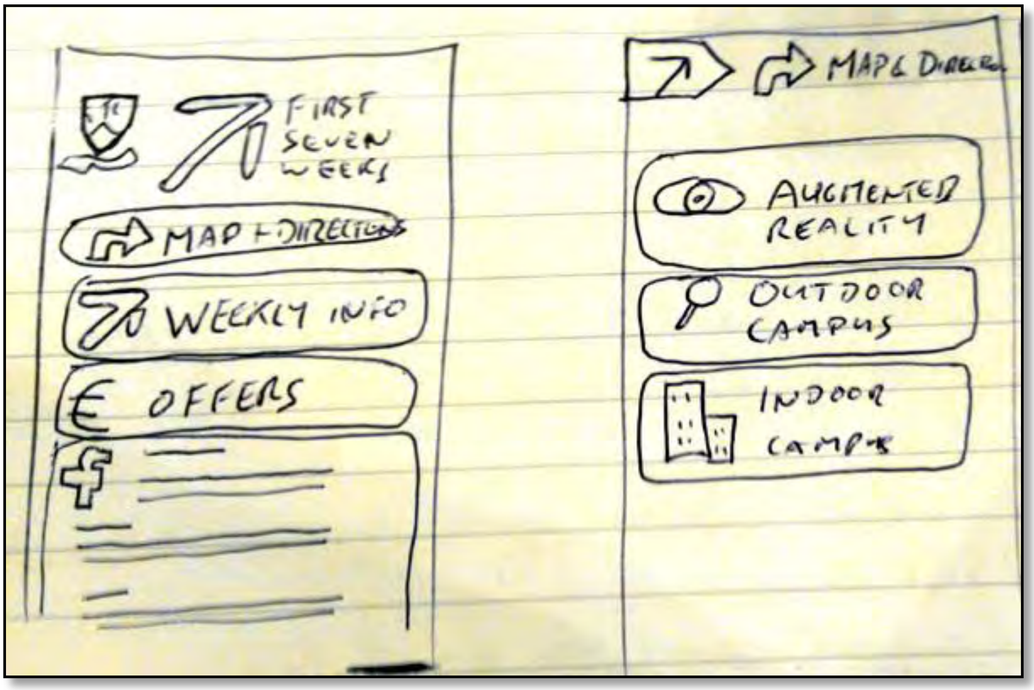


Figure 3. UI Sketches

These sketches were then elaborated on using an iterative series of design mock-ups as shown in Figure 4. These mock-ups facilitated the narrowing of focus with regard to decisions on which colours, styles, logos and interaction artefacts (e.g. buttons, menu system etc) to use.

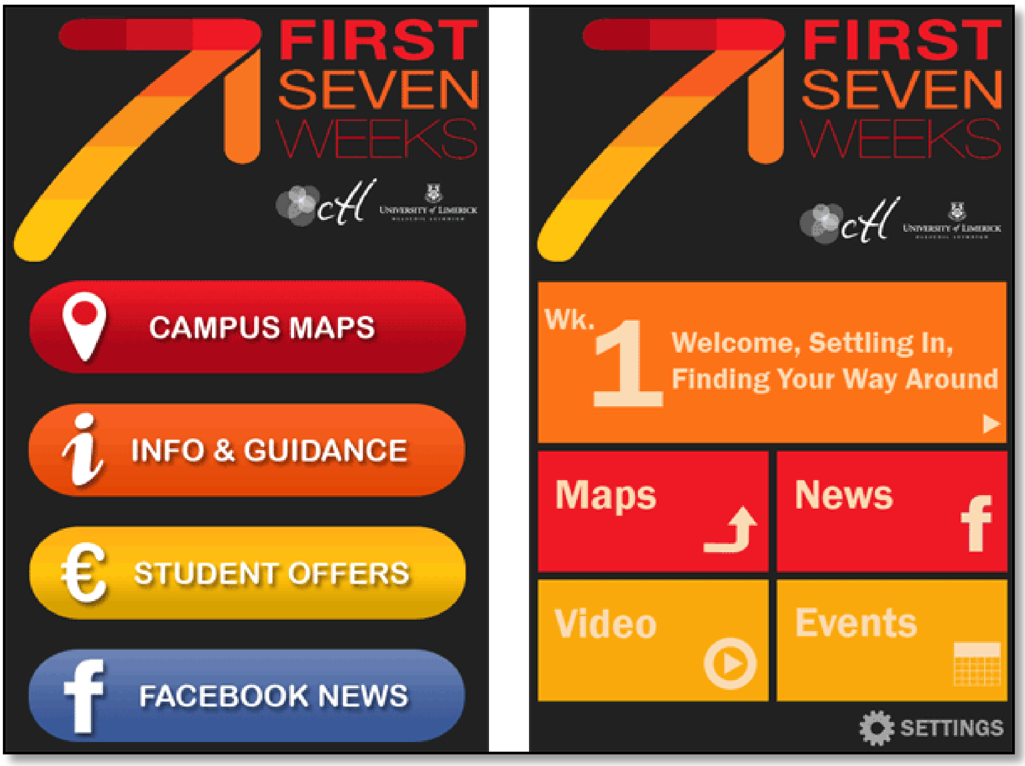


Figure 4. UI Mockups

These sketches and mock-ups allowed a decision to be made regarding the structure of the home screen and menu system of the application and website also. It was decided that a hub and spoke design pattern[22] be used to portray the menu system options on the home screen. This allows for efficient use of the viewable screen by

[22] Hub and Spoke Design Patterns - http://www.uxbooth.com/articles/designing-for-mobile-part-1-information-architecture/

showing the priority menu items without the user needing to scroll excessively. A series of wireframes were created to visualise the design and structure of the application screen, based on the requirements and the feature list. These wireframes are shown in Figure 5.

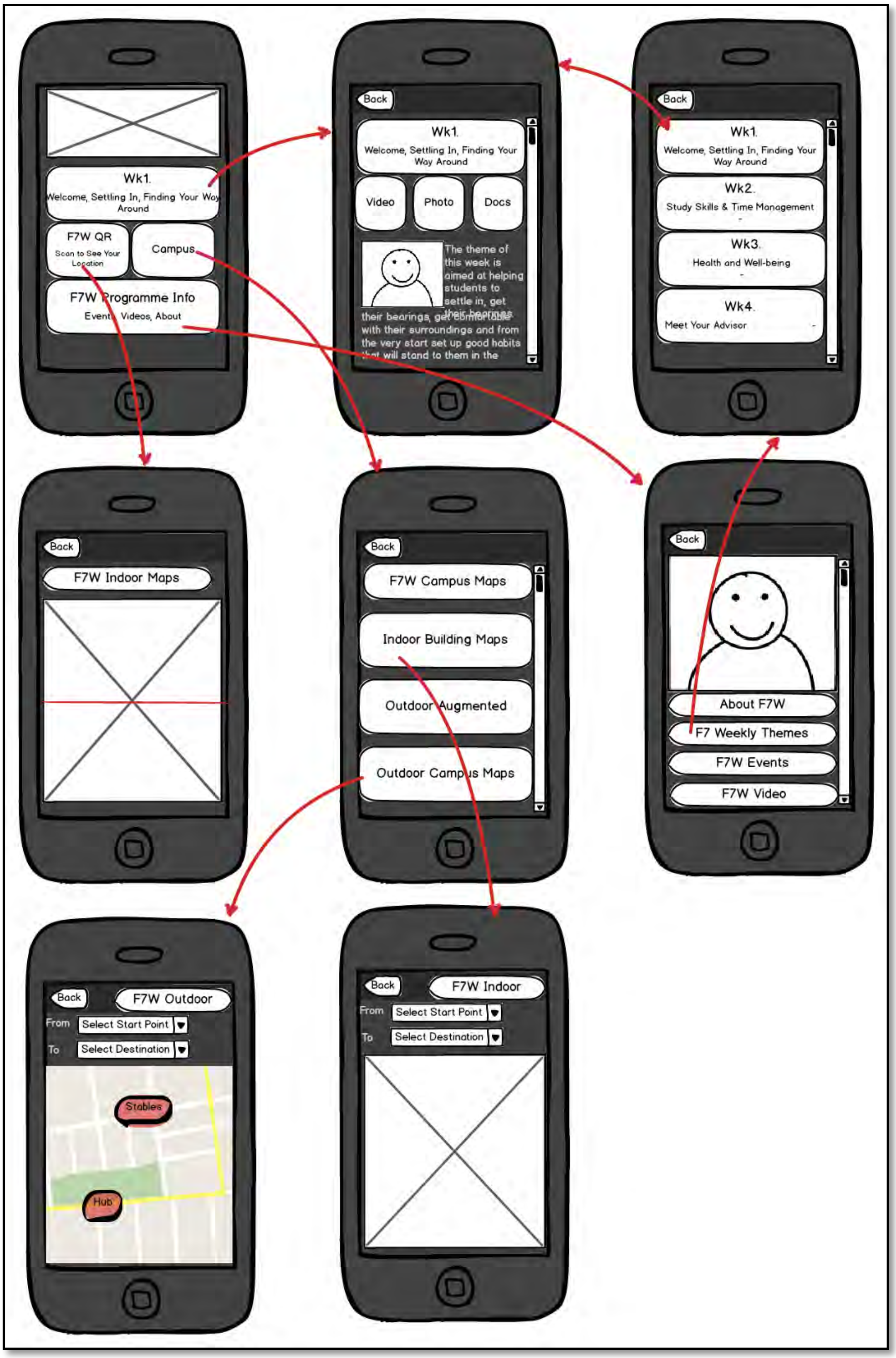


Figure 5. UI Wireframes

These wireframes combine the evolution of the initial design from the early sketches in Figure 3 and mock-ups in Figure 4, with the features list and requirements. A key requirement of this combination process was to ensure that the wireframes produced, and later the Android application itself, reflect and employ as much as possible the principles of usability (Learnability, Flexibility and Robustness) as defined by Dix (2004).

3.5.3.3. Splash Screen and Consent Disclaimer Screen

The splash screen of the Android application, as shown in Figure 6, was designed to be displayed for three seconds when the app is run. The screen includes the logos of The First Seven Weeks Programme, The University of Limerick, The Centre for Teaching and Learning and The Computer Science and Information Systems department, to symbolise the project of collaboration between the two entities in the university. The logo of the National Digital Learning Resources was also included; a body which part funds the Centre for Teaching and Learning. During 2012 The University of Limerick celebrated its 40th year of Innovation and the logo for this campaign was also included on the splash screen. The Android application was an example of a more recent innovation that has been produced in the university.

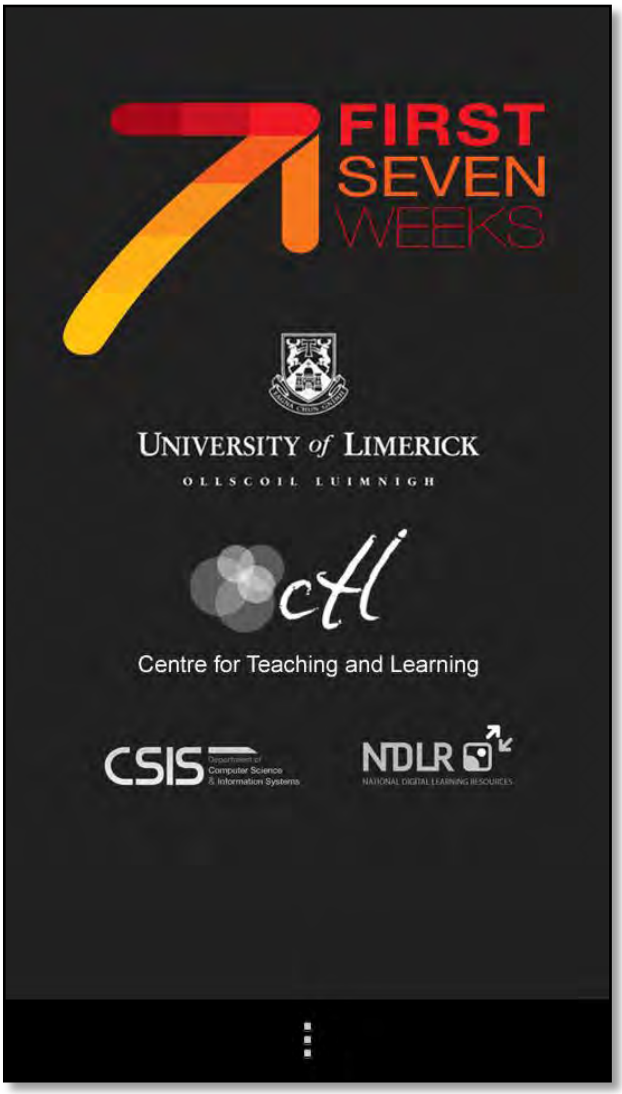


Figure 6. Splash Screen

When the app was run for the first time, the Consent Disclaimer screen was displayed to the user when the splash screen fades out. The Consent Disclaimer screen, as shown in Figure 72 in Appendix B, was designed to display information about the collaborative research project undertaken by the IDC and CTL, and allowed the user to opt-in or opt-out of participating in the research project. By opting in, the user confirmed their age as over eighteen years and consented to allow anonymous interaction metrics from the app to be analysed as part of the research project. The user could also optionally specify their study discipline. The screen also informed the user that the consent can be changed at any time from within the app by accessing the Disclaimer menu option. The screen also included contact details in the form of email addresses for the primary investigator and researcher, the research project supervisor, the Centre for Teaching and Learning manager and the Faculty of Science and Engineering Research Ethics Committee chairperson. All of the information and the method of consent implemented in the Disclaimer Consent screen received approval from the Faculty of Science and Engineering Research Ethics committee as described in section 3.8. The research project information and contact details were also included on the About the F7W Programme page within the Android application and on the mobile website.

3.5.3.4. Hierarchical Menu System

Beyond the home screen which uses the hub and spoke navigation pattern (Figure 8), the remainder of the menu system used the nested doll design pattern [23] to display the hierarchical nature of the menu system, as shown in Figure 7. The options on each level of the navigation tree were displayed as large, image-based, clickable menu items in a scrollable list. The navigation bar across the top of the screen allowed for vertical navigation back up the navigation tree all the way back to the homescreen. As described in the next section, this navigation style adhered to many of the principles of usability including familiarity, consistency, pre-emptive flexibility and browsability.

---

[23] Nested Doll and Hub and Spoke Design Patterns: http://www.uxbooth.com/articles/designing-for-mobile-part-1-information-architecture/

Figure 7. Hub & Spoke Home Screen

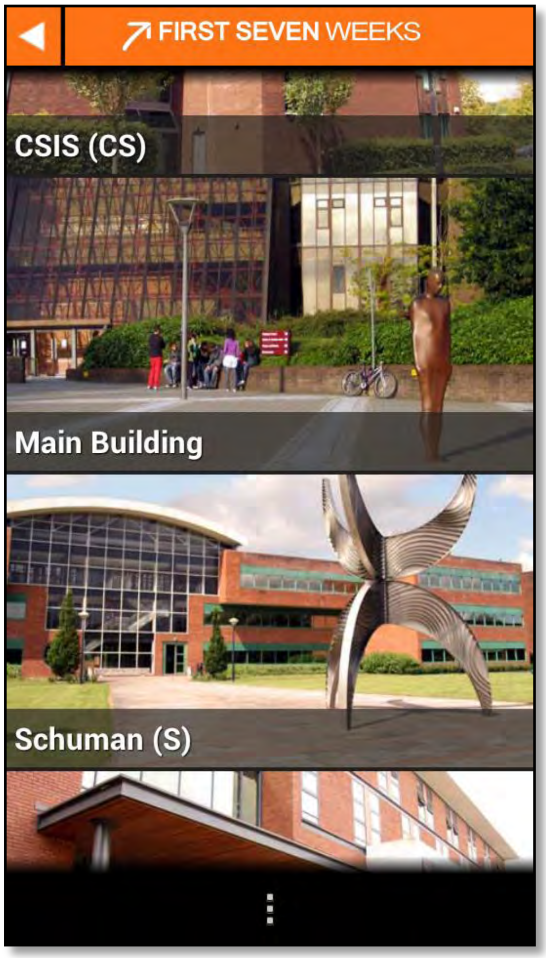


Figure 8. Nested Doll Menu Screen

The First Seven Weeks programme information consists of pre-set weekly theme information, dynamically changing weekly content like photos and video, and other general information about the programme. This content was accessed using the hub and spoke home screen primarily, allowing the user to navigate the menu hierarchy as shown in Figure 5.

3.5.3.5. First Seven Weeks Programme Content

The main outcome for the CTL of the collaboration project that allowed the development of the Android application and mobile website was to deliver the First Seven Weeks Programme information. The information included details about the programme, a list of recommended books, a link to the programme Facebook page and a list of the supports and resources available to students, as well as documents, photos and video, categorised into the seven weekly themes. An example weekly information screen is shown in Figure 9. All of this information was accessible from the home screen of the application via the hierarchical menu system. The first item on the home screen displayed a link to whichever weekly theme was currently active, during the period that the First Seven Weeks Programme operated. Otherwise a link to the list of all the seven weekly themes was displayed.

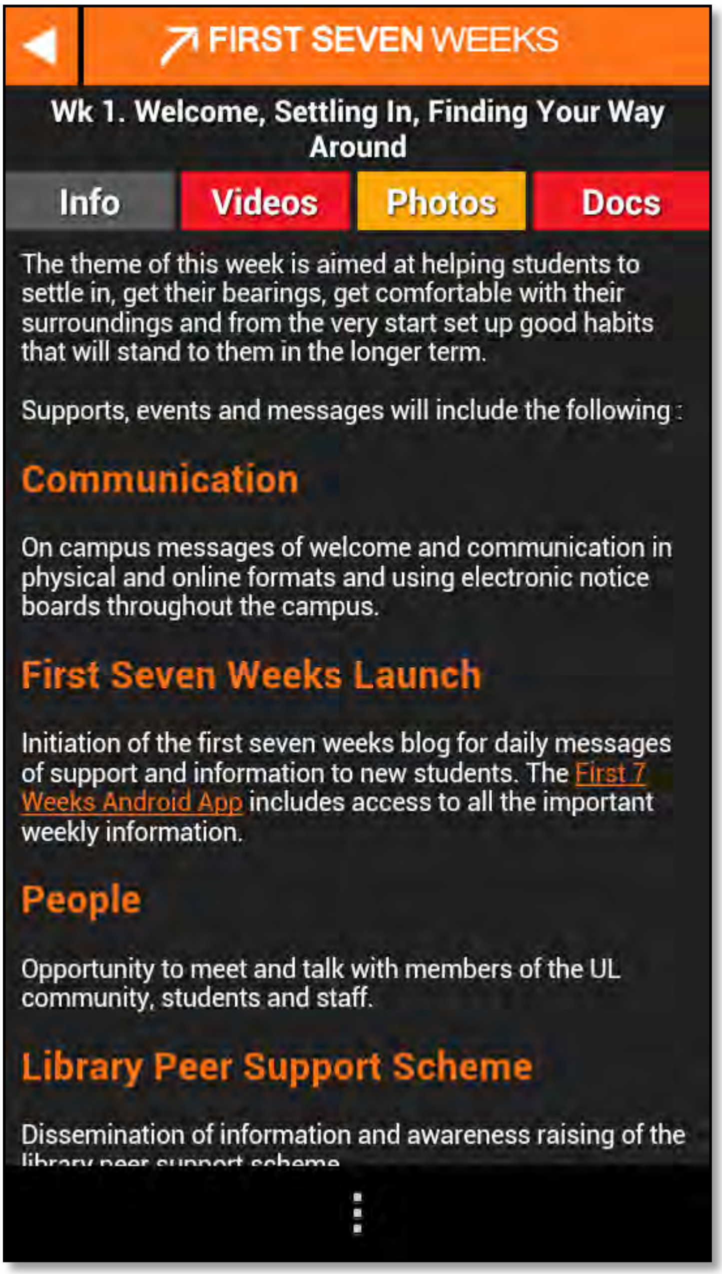


Figure 9. F7W Weekly Information

3.5.3.6. Content Management

The First Seven Weeks mobile website (http://first7weeks.ul.ie) was delivered using a responsive template within a Drupal CMS instance. The purpose of the mobile website was to deliver the same First Seven Weeks Programme content as was delivered using the Android Application and to also provide a link to download the

Android application on the Google Play Store. All of this content was managed by and could be changed and updated using the Drupal CMS.

3.5.3.6.1. Responsive Design

Responsive design allows for the display of the site content to adapt to the resolution of the screen that is being used to access it. This functionality is particularly important for sites that are accessed using mobile devices due to the variety of different screen sizes and resolutions. Since the target audience for the site was users accessing the content on mobile devices, the responsive template functionality was a priority. This basic functionality was delivered using the Omega[24] Drupal base theme. An additional graphic design was created to match as closely as possible the design of the Android application as described in section 3.5.3.2. This was done by presenting the menu items as large clickable images, structured using the Russian doll navigation style as shown in
Figure 8. Further responsive functionality with regard to images was delivered using the Adaptive Images Styles[25] Drupal module, which appropriately and automatically scaled images on the site depending on the resolution of the target device.

3.5.3.6.2. Drupal Content Types

The Drupal CMS allowed for content to be displayed in many different custom formats using Drupal content types[26]. A content type is similar to a Drupal node, whereby an admin user can create an instance of it and enter in content to be

---

[24] Omega Drupal Base Theme: https://drupal.org/project/omega

[25] Adaptive Image Styles Drupal Module: https://drupal.org/project/ais

[26] Drupal Content Types: https://drupal.org/node/21947

displayed, however the fields within the content type, and the method with which these fields are displayed, are all customisable. Several content types were defined for the First Seven Weeks mobile website to cater for the display of homepage items, menu items and pages of dynamic content that are accessible on first7weeks.ul.ie and within the Android application.

3.5.3.6.3. Content Delivery Channels

While the primary use of the Drupal CMS was to deliver content on the First Seven Week mobile website, it also served as the master source of the content and allowed for the content to be delivered on multiple channels, such as via the Android application. Content from the Drupal CMS was delivered via the Android application in two ways. The dynamic weekly information such as photos and video is an example of the first way that content was delivered. This was achieved using a custom content type designed to not include the First Seven Weeks graphical header. This content was then accessed using a container page which loaded the content into the mobile website dynamically depending on which type of content the user wished to view. A similar method was used within the Android application to load the dynamic content using an Android WebView[27] component which allowed online content to be displayed when the device was connected to the internet, as shown in Figure 10.

[27] Android WebView: http://developer.android.com/reference/android/webkit/WebView.html

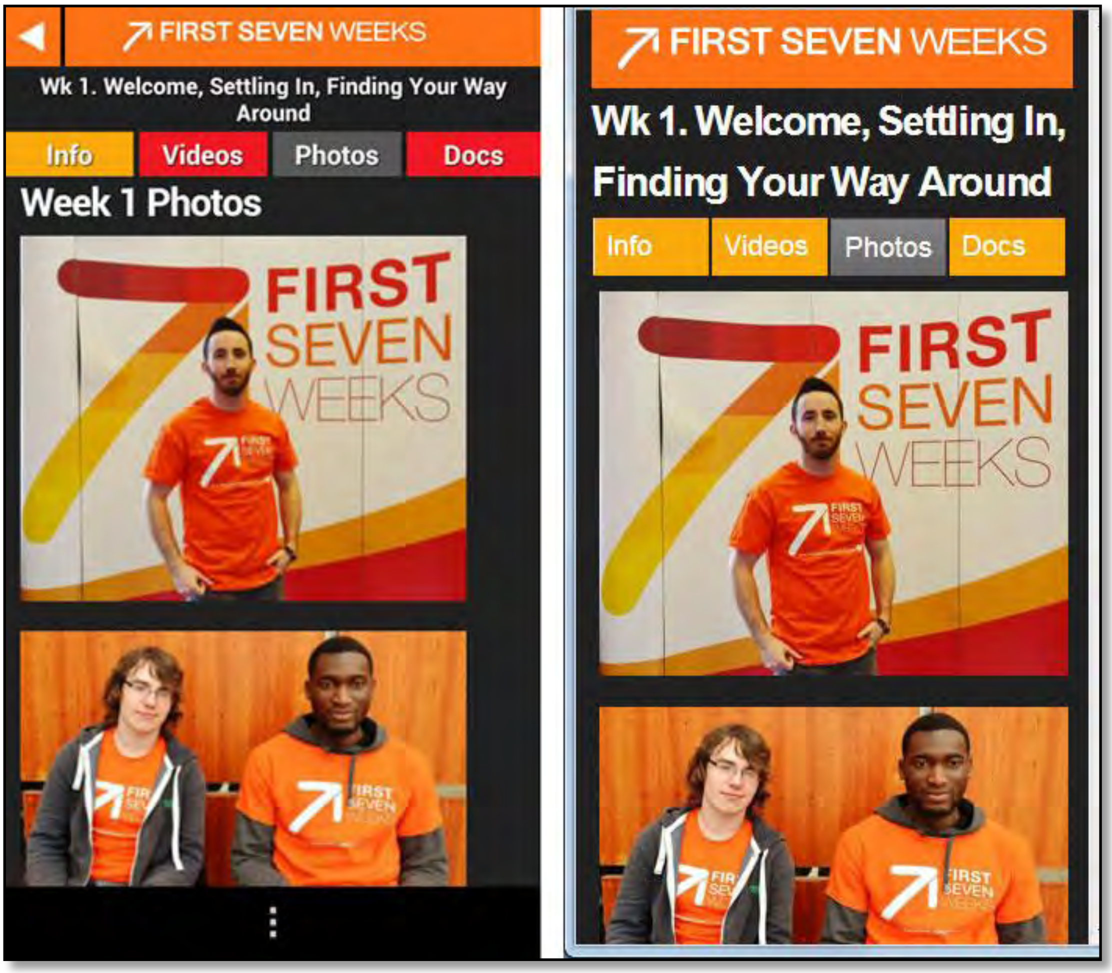


Figure 10. Dynamic Web Content in Android App & Mobile Website

The second method of content delivery used in both contexts was a JSON webservice. Using the REST Server[28] and RESTful Web Services[29] Drupal modules, Drupal content entities such as page nodes, menu item listing and custom content types could be requested using a REST URL. This content was then delivered in response to the request in the form of a JSON string. The Android application parsed

---

[28] REST Server Drupal Module: https://drupal.org/project/rest_server

[29] RESTful Webservices Drupal Module: https://drupal.org/project/restws

the content delivered via the JSON string and updated the SQLite database with the newer content. Examples of JSON response strings are included in Appendix C.

3.5.3.7. QR Code Scanning

QR Code scanning was utilised in two scenarios to allow the user to interact with the Android application and the mobile website. As part of the deployment of the Android application and mobile website, QR codes were generated and printed on A4 sheets of paper and placed within the stairwells on every floor of the main building in the University of Limerick. Additional QR codes were generated and placed within the entrance of the remaining nine undergraduate buildings on campus. Examples of both of these deployments can be seen in Figure 11.

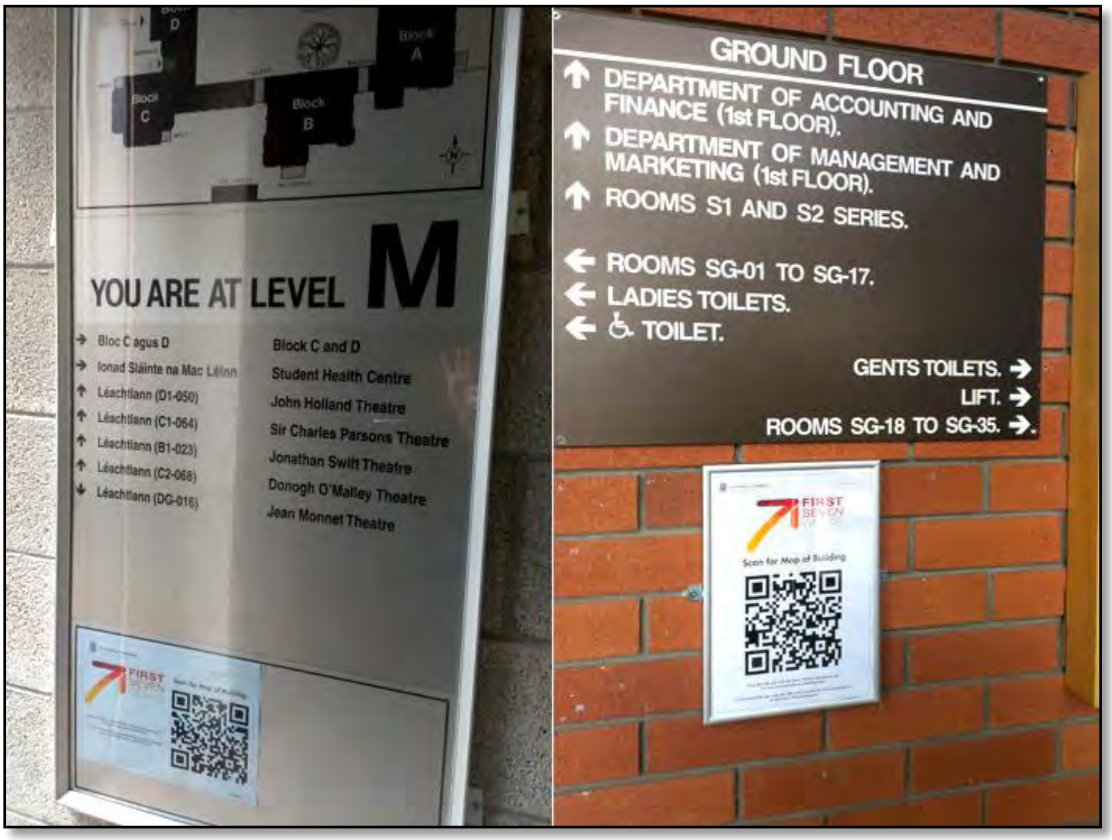


Figure 11. QR Code Placements

The initial scenario whereby a user could interact with this experiment was by scanning the QR code with their smartphone. In doing so, the user navigated to a page on the mobile website. This page[30] contained links to information about the First Seven Weeks Programme and also included a link to download the Android application. The second scenario where QR code scanning was used was in the indoor mapping feature of the Android application. This functionality was developed using the ZXing library, which allowed control to be passed from the Android application to a barcode scanner, which when complete returned the URL encoded within the scanned QR code. By scanning any of the QR codes using the Android application using the menu option on the home screen or the mapping screen, the user could view the location of the QR code on the indoor floor map, or rather the location of the node that the QR code is assigned to, and thus their current location. This mechanism provided the user the ability to re-orient them-selves during the process of wayfinding. This mechanism was a key component of the mixed granularity indoor wayfinding functionality as demonstrated by this thesis and is described in more detail in the next chapter.

3.5.3.8. Gathering of Usage Data

A key requirement of this deductive experiment was to capture empirical data on how each user interacts with the Android application and mobile website. This was achieved in two ways. Firstly, Google Analytics and Google Analytics for Mobile

[30] First Seven Weeks Mobile Website Landing Page: http://first7weeks.ul.ie/download.html

v1.4.2[31] were used to track user interactions on the mobile website and Android application respectively. These external services allowed for reporting on which content areas of the mobile website and Android application were accessed most frequently, for how long and from which geographic location. The data gathered from Google Analytics was not sufficient however in tracking a particular user's sequence of interactions, in particular within the indoor wayfinding feature of the Android application. This data was needed to ascertain if any patterns of use existed in the user's interaction with the wayfinding feature, to allow the feature to be evaluated. Logging functionality was developed as part of the wayfinding feature to allow this data to be captured using the device ID of the Android phone. The analysis of this data and the results therein are presented in chapter 6.

3.5.3.9. Adherence to the Principles of Usability

The three principles of usability are defined as Learnability, Flexibility and Robustness (Dix, et al., 2004). The design and implementation of the First Seven Weeks Android application was designed to employ and reflect these principles where possible, as described in the following sections.

3.5.3.9.1. Learnability

The principle of Learnability is sub-categorised into the areas of Predictability, Synthesisability, Familiarity, Generalizability and Consistency. The Android application exhibits a number of these properties.

[31] Google Analytics for Mobile - Google Analytics for Mobile: http://www.google.ie/analytics/mobile/

The predictability of a system is categorised by the transparency of operations available for execution within a system, and the ease at which a user can determine the effect of these operations. The image based menu system of the Android application was designed to convey the main available operations of the application. The predictability of these operations was enforced by the use of contextual images in the menu system to convey the effect that will occur should a user select a menu item. For example, the QR scan button on the home screen of the application contained an image of a QR code and the maps button on the home screen contained an image of a floor map, as seen in Figure 7.

The synthesisability of a system is measured by how effectively change caused by operations is made transparent to the user, thus allowing the user to create a mental model of how the system will behave, enforced by the predictability of the system. The touchscreen interface allowed the Android application to present feedback to most of the operations performed by the user. When menu items were selected, the menu item was highlighted for a moment to enforce the selection of the user before moving to the new screen. The indoor wayfinding feature of the application employed the method of colour and shading differences to signify when an item was in a highlighted state, for example, when a destination point was chosen the “To” button at the top of the screen changed to a green colour, and an X button appeared next to it allowing the user to cancel the selection, as shown in Figure 12. This same interface pattern was used within the map point modal screen.

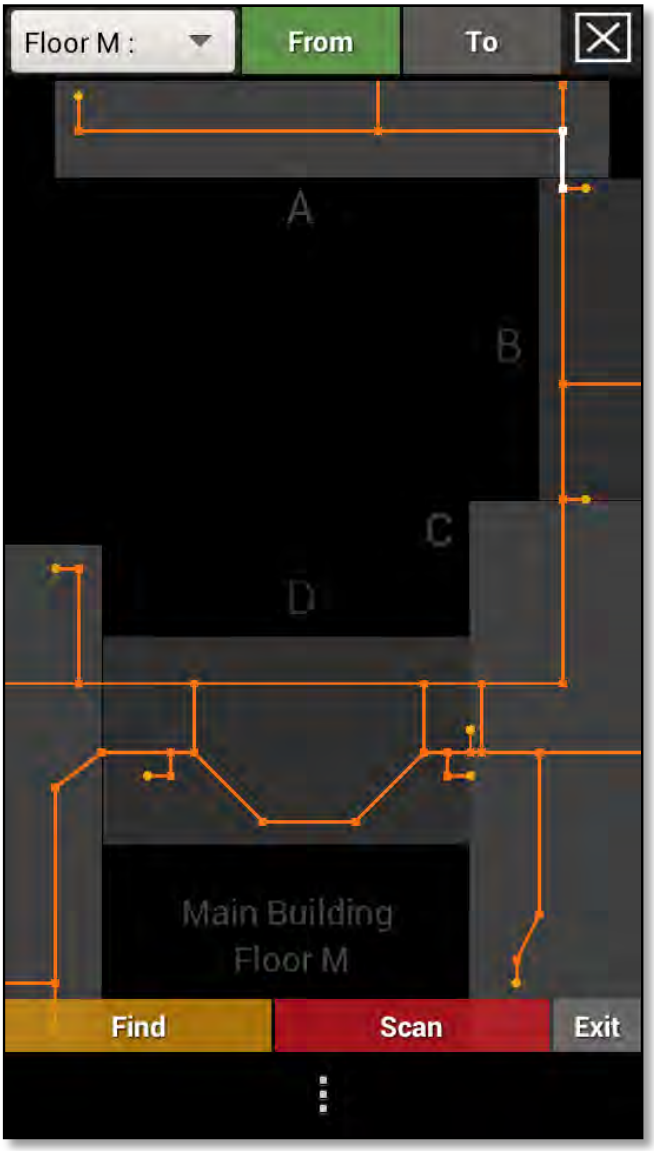


Figure 12. Mapping Interface: To & From Buttons

The familiarity of a system measures how usable the system is for new users that have no previous experience of the system but have experience of other systems. The image based menu system with the large touchable areas of each menu item enforced the familiarity of the Android application for users with previous experience of using a smartphone touch interface. The zooming functionality within the indoor wayfinding feature was activated using the pinch and zoom touch gesture, which was also familiar to users with experience of smartphone touch interfaces. Throughout the Android application, modal based outputs were coupled with an X icon to allow the modal to be dismissed, which was familiar to users with prior experience of user interfaces, as shown in Figure 13.

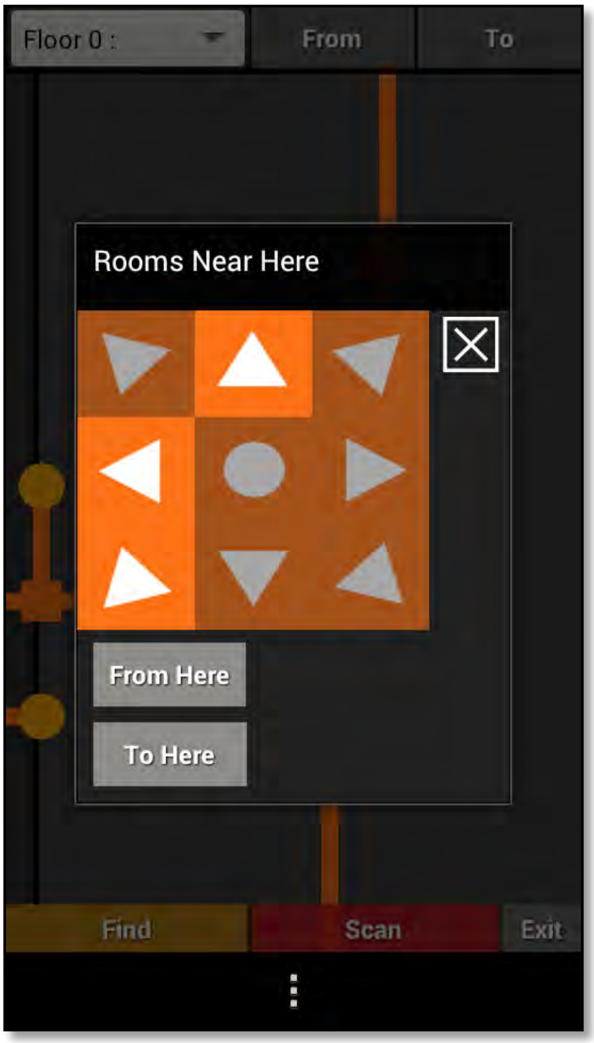


Figure 13. Modal Popup

The generalizability of a system is a measure of how a user can perform the same or similar actions in the same way in multiple contexts, making the system easier for the user to predict outcomes of any particular operation. The consistency of a system is a measure of how similar the system is with respect to another aspect of the system, for example, constituency in how menu items are displayed and selected or how alert information is displayed. An example of generalizability and consistency within the Android application can be seen within the indoor wayfinding feature. Operations within the mapping feature were made transparent to the user within both the context of each building and each floor with each building. Operations available in the context of the building selected were displayed at the bottom of the map screen irrespective of which building is selected. These operations allowed the user to find any room within the building, scan any QR code within the building or exit the current selected building and return to the building menu list. Operations available in the context of the building floor selected were displayed at to the top of the map screen irrespective of which floor was selected. These operations allowed the user to change the selected floor and display a route on the map by selecting a start point and an end point on the selected floor. The floor map displayed also allowed the user to explore the points of interest within each area of the map by tapping a map point, which displayed a modal screen. This interface pattern was consistent for every map, irrespective of which building or floor was selected, as shown in Figure 14.

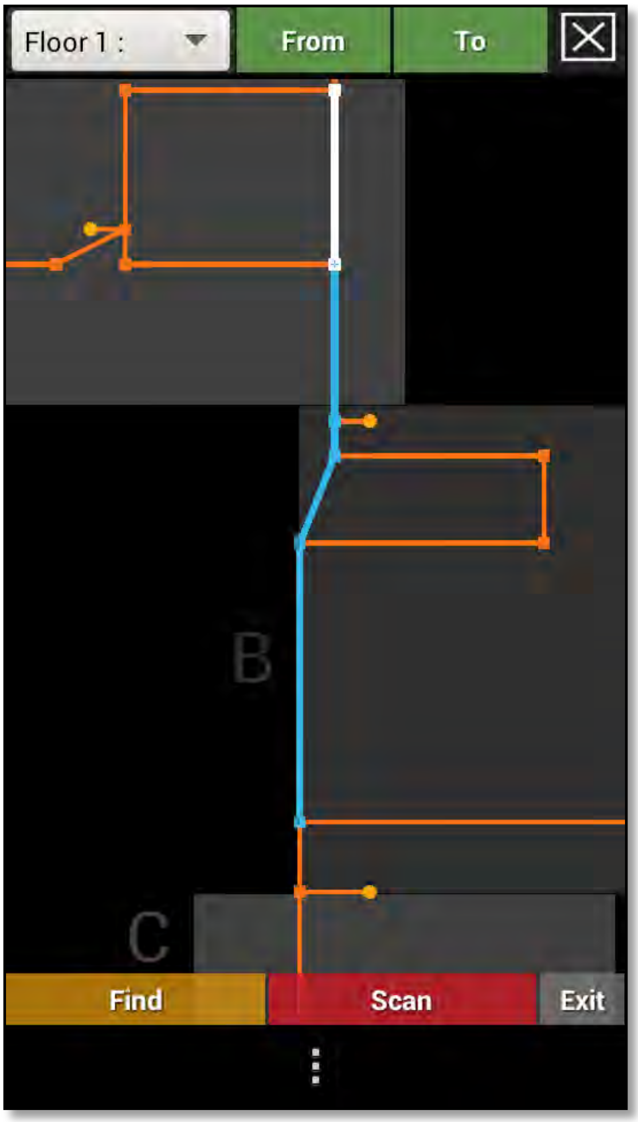


Figure 14. Mapping Interface: Consistent UI Elements

3.5.3.9.2. Flexibility

The principle of Flexibility describes how information is exchanged between the user and the system. The flexibility of a system can be described in terms of the concepts of Dialog Initiative, Multi-threading, Task Migratability, Substitutivity and Customizability. The Android application was designed to be flexible in the context of a number of these concepts.

Dialog initiative describes how the interaction between the user and the system is actioned, especially in the context of the activation of system operations. The Android application was designed to be user pre-emptive as much as possible, whereby the user decided which operations to activate or deactivate. For example, the menu system allowed the user to select which of the main features to activate, and the back button within the menu system allowed the user to navigate back up the menu tree. The only operation which was system pre-emptive within the application was when the user initiated the QR scanner. The sequential nature of scanning a QR code necessitates the system pre-emptive nature of this feature within the application, whereby the user must scan a QR code once the QR scanner was activated in order to proceed to the next step in the sequence. The user did however have the option of exiting out of the QR scanner, but would not be able to proceed to the information display step of the sequence without scanning a valid QR code.

Multi-threading in terms of flexibility describes the ability of the system to support more than one type of interaction at any one time. The Android application was designed with interleaved multi-threading in mind, whereby there was a temporal overlap between tasks. Interleaved output was exemplified in the indoor wayfinding feature of the application. At any one time, the floor currently being viewed was displayed at the top of the screen. When a user tapped on a map point a modal popup was displayed allowing the user to view a list of rooms around that point. During this process however, the floor identification was still visible, as shown in Figure 13.

Task migratability describes the ease at which control of execution can be transferred between the system and the user. The Android application relied heavily on this migration in the operation of the indoor wayfinding functionality. Execution was transferred to the user to select which building and floor to view when the task of wayfinding was first executed. The execution was transferred back to the application in order to retrieve and display the information. The filtering of the information displayed was again a function of the user, executed using the touch interface to move and explore the map points and in selecting a point of interest to find or a route to display, as shown in Figure 15.

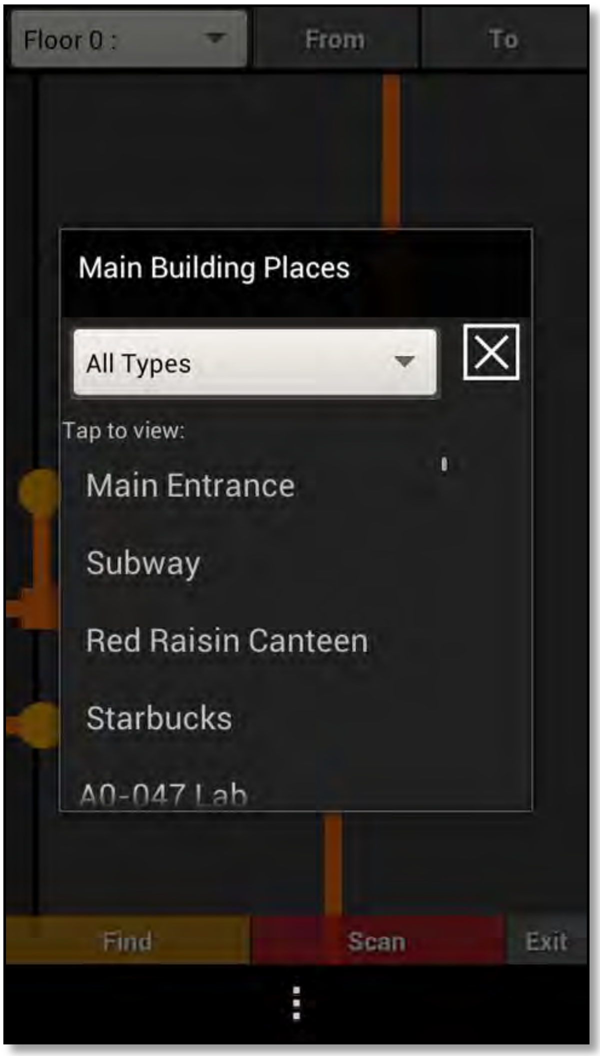


Figure 15. Room Filter List

For each particular task, the application was designed to guide the user journey and transfer control to the user where appropriate. Another example would be the task of scanning a QR code, which was dependent on the user taking control of the execution, but does not result in a display of information until the control was transferred back to the application with the relevant input in order to process and display the relevant information, for example, showing the location of the QR code on a floor map (Figure 20).

The substitutivity of a system describes the ability to take input and deliver output in different formats and values where relevant. The usability of the indoor wayfinding feature of the application was designed with this as a core principle. Input was taken from the user in multiple formats, whereby the user selected a start point from a list of rooms, by tapping a point on the map or by scanning a QR code. Similarly, output was displayed in multiple ways such as the rooms on a floor were displayed in a full list (Figure 15) but also displayed in a positional context when map points were explored (Figure 13).

The customizability of a system describes how a user interface can be adapted by the user (adaptability) and automatically by the system (adaptivity). The implementation of this concept within the Android application was an area of potential future work. An example of possible adaptability would be allowing the user to define a list of favourite buildings, floors and/or rooms within the application, allowing for expedited access to this information. An example of possible adaptivity would be the application detecting the most visited areas of a particular floor or a particular building and sorting the relevant lists of buildings and floors by order of most accessed. Another example of both adaptability and adaptivity would be the application detecting the most visited areas and provided suggested routes to the user, allowing the user to save these routes as favourite routes.

3.5.3.9.3. Robustness

The principle of Robustness describes a system that supports the user in successfully achieving a set of goals or tasks. The robustness of a system can be described by the principles of Observability, Recoverability, Responsiveness and Task Conformance. The Android application adheres to a number of these principles.

The observability of a system dictates how the state of a system is represented by the system and thus perceived by the user. It is further defined in terms of browsability, defaults, reachability, persistence and operational visibility. The Android application was designed to conform to these principles however possible future work does remain in improving the level of conformance. The browsability of the Android application can be addressed firstly by the design and implementation of the main menu system. The menu employed a nested doll design pattern to display the hierarchical nature of the menu system (
Figure 8). This pattern allowed the user to navigate each sub tree of the navigation tree with a transparent view of all the sub-items at any particular selected level. While this pattern did not allow for visibility of the whole navigation tree, it allowed for easy vertical navigation up and down the tree while attempting to reduce the cognitive overload of the user by reducing the maximum number of navigation levels in the tree to three levels. Browsability was also taken into consideration in the design of the indoor wayfinding feature. While core principle of this feature was to allow the user to explore the environment during the act of wayfinding and thus was in slight contradiction to the principle of browsability whereby all the information

should be as visible as possible, the application does provide this information in numerous browsable formats. For example, the rooms located on a particular floor could be accessed from a list, or explored by the user using the mapping interface.

The Android application used the dynamic defaults principle to calculate and display the ground level floor of a building and display this floor first when a building was selected (
Figure 8). The principle was also employed when a QR code was scanned by the user, thereby setting that point on the map as a default start point. The principle was employed again on the home screen where the application calculates the current date and displays the link to the relevant weekly theme information, allowing the current weekly information to be accessed quickly while the First Seven Weeks programme is taking place (Figure 7).

The ability of the user to traverse the navigation tree allowed the principle of reachability to be measured in the context of each operation of the application. In terms of the indoor wayfinding and weekly information display features however, potential additional work can be done in increasing the reachability of this information. Up to this point the application displayed this information at the terminating point in the navigation tree, with the exception of the current weekly theme which was dynamically linked from the home screen depending on the date of access.

The Android application was designed with the persistence of information in a visual format as the primary method of output. Items selected or highlighted by the user are shaded and coloured to signify the persistent change in state. An update notification icon (which can be seen in Figure 7) was also used to relate the availability of updated information to the user, which remained on display until the user executes the download and update task. The visibility of operations was a paramount principle followed in the design of the Android application, as described in Section 3.5.3.2.

The recovery of a system measures the ability by the system or the user to reach a particular goal following the recognition of a previous error. Forward recovery involves movement from an error state to a desired goal and backward recovery involves attempting to undo the error and progressing differently to a desired goal. The Android application was designed to employ both forward and backward recovery where appropriate. The image based menu with the application allowed for backward recovery whereby if the user selected a menu item in error, the user can traverse back up the navigation tree to the point before the erroneous menu item was selected. Forward recovery was employed as a principle in the design of the indoor wayfinding feature. During wayfinding, if a user became lost, they could accept the erroneous state and attempt to reorient themselves by scanning a QR code to show their current position and re-engage in wayfinding from that position.

The responsiveness of a system is a measure of the rate of information exchange between the system and user, in particular in the speed of response of a user interface. The goal for the Android application was to be as responsive as possible. As a result, the application was designed to store as much relevant data as possible on the device to allow for fast response times when calculations are needed upon that data, for example in computing the route to display on a floor map. The responsiveness of some features however was degraded in exchange for the availability of up to date content. Weekly videos, documents and photos were available for each First Seven Weeks programme weekly theme but were not stored on the device and could only be accessed when an internet connection was available to the device. In this scenario the responsiveness of the application to display this information was low however the user was guaranteed that the information being displayed was the most up to date.

The principle of task conformance describes the level at which the tasks represented by the interface of a system match the tasks as understood by the user and supported by the system. In the context of the Android application, the tasks of menu navigation and information display were at a high conformance level. The overall deployment of the application was also at a high conformance level due to the inbuilt multiple resolution capabilities of the Android environment. The application was built to support the four resolution densities[32] of ldpi, mdpi, hdpi and xhdpi as defined in the Android environment. The task of indoor wayfinding however was not at a high conformance level by design. The purpose of the indoor wayfinding feature of the application was to deploy and evaluate a mixed granularity approach to indoor wayfinding as described in Chapter 4. This approach purposefully did not pinpoint the location of POIs (e.g. rooms) on a map but instead displayed their general location between navigation points in order to allow the user to experience an exploration experience. As a result, the user's perception of an indoor wayfinding task may differ from the task supported by the system, resulting in low task conformance. The results of the enjoyment factor question in the third deductive experiment described in section 5.3.1.5 allude to this.

---

[32] Android Multiple Screen Resolution Support:
http://developer.android.com/guide/practices/screens_support.html

3.6. Deployment

The deployment of the Android application and mobile website was split into two stages. Firstly, the mobile website was deployed to the Amazon AWS cloud based infrastructure. A free AWS Elastic Cloud Compute (EC2) micro instance webserver was instantiated in the Amazon US East north Virginia data centre. The instance was configured with a LAMP (Linux, Apache, MySQL, PHP) stack and 1 elastic IP address. A Drupal site was installed and configured on this webserver. The New Relic[33] monitoring service was also installed to allow analytics to be gathered on the performance of the Drupal site, which are presented in Chapter 5. The deployment using the amazon AWS cloud computing service allowed for flexibility and scalability in times of high traffic to the mobile website and invocations of the JSON RESTful webservices from users of the Android application.

The second stage of the deployment was the publication of the Android application to the Google Play store. The process of publication involves numerous steps[34] including the digital signing of the application .apk file, uploading the .apk file via the developer console and providing the necessary description and screenshots of the application.

Both stages of deployment took place at the start of September 2012 and the Android application and mobile website remained live for purposes of this experiment until November 2012.

---

[33] New Relic: http://www.newrelic.com

[34] Google Play Store Launch Checklist: http://developer.android.com/distribute/googleplay/publish/preparing.html

3.7. Dissemination

The success of the three deductive experiments of this thesis was dependent on the amount of users that fill in the online questionnaires and interact with both the application and website. In order to ensure a high number of participants in each experiment, a series of dissemination initiatives were executed. To invite participants to fill the first and third experiment questionnaires, an email was sent to all first year students with the link to the questionnaire. Follow up emails were also sent within two to three weeks to remind users to participate. The dissemination of the Android application and mobile website required more high profile marketing among the student body in the University of Limerick, which included a number of initiatives. A presentation was given to the group of first year orientation guides as a part of their preparation for their duties undertaken during the orientation week of 2012. This presentation described the functionality of the Android application and mobile website, and encouraged each guide to recommend the use of the indoor wayfinding feature of the application to first year students to find their way around campus. The QR codes placed in the stairwells of the main building and within the entrances of the other undergraduate buildings also helped raise the awareness of the Android application and mobile website. An additional marketing initiative was enacted during orientation week by placing the required QR code at multiple points within the registration hall, to allow incoming first year students to scan the QR code and access the mobile website and Android application while waiting in line to register, pay their fees and collect their student card. The CTL also conducting a large initiative to market the mobile website and Android application by placing a QR code on all of the printed posters for the First Seven Weeks programme, as well as distributing mouse mats with the QR code printed on them, as shown in Figure 16.

Figure 16. First 7 Weeks Mouse Mat with QR Code

A presentation and photo-shoot was also arranged with the President of the University of Limerick, Professor Don Barry, Associate Vice President Academic, Professor Sarah Moore, IDC Senior Member, Dr. Mikael Fernström and the author, Daryl Feehely. This photo, as shown in Figure 17, was distributed to the local newspapers along with a press release about the mobile website and Android application.

Figure 17. F7W App Launch Photo-shoot

A significant amount of online marketing of the mobile website and Android application also took place. The press release and photo was also displayed on the websites of the university[35], the local press[36] and national news websites like Silicon Republic[37] and Campus.ie[38], an example of which is shown in Figure 18.

---

[35] New Smart Phone App sends UL first year Students in the Right Direction, 10/09/2012: http://www.ul.ie/news-centre/news/new-smart-phone-app-sends-ul-first-year-students-in-the-right-direction

[36] UL helps students get to lectures on time!, 14/09/2012: http://www.limerickleader.ie/news/business/ul-helps-students-get-to-lectures-on-time-1-4255328

[37] Android app guides first-year students around UL campus (video), 14/09/2012: http://siliconrepublic.com/careers/advice/category/49-apps/item/29220-android-app-guides/

[38] New Smart Phone App sends UL Freshers in the Right Direction, 13/09/2012: http://campus.ie/news/college-news/smartphone-app-ul-freshers

Figure 18. Dissemination on SiliconRepublic.ie

A YouTube video[39] describing the mobile website, the features of the Android application and the relevance of the QR codes placed around campus was created and uploaded to YouTube and the Google Play store, as shown in Figure 19.

[39] UL First 7 Weeks Android App (Indoor Maps & Info): http://www.youtube.com/watch?v=WnQ5wHpYcow

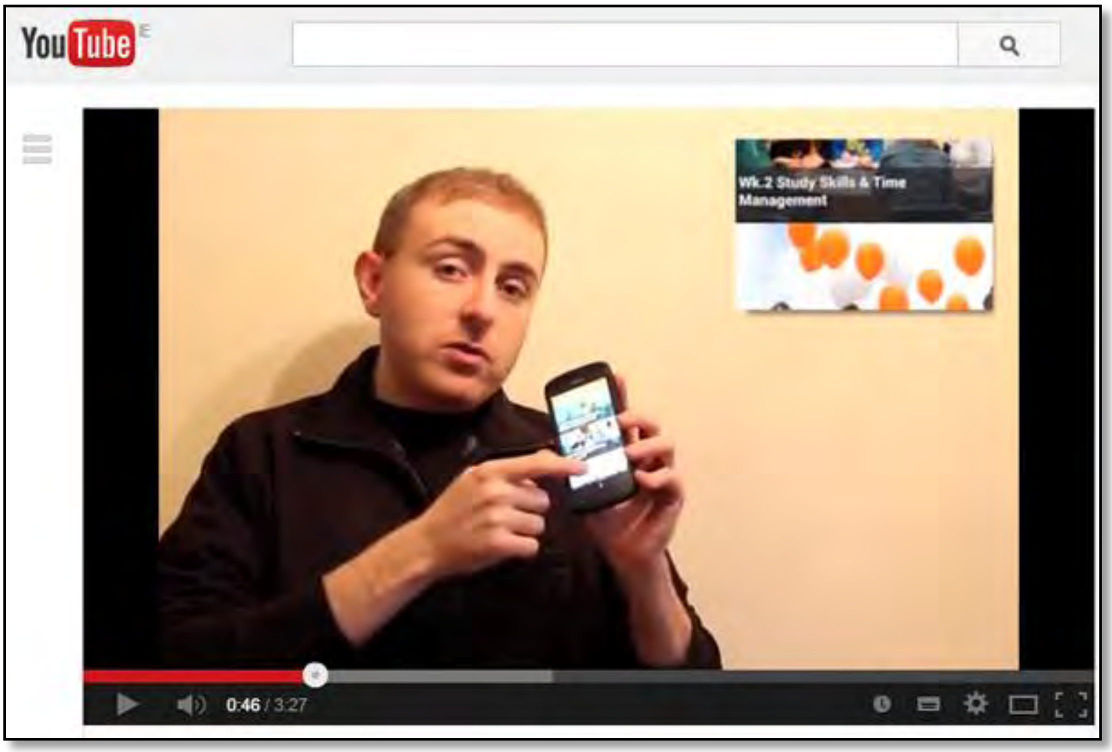


Figure 19. First & Weeks App YouTube Video

This video was also distributed via the First Seven Weeks Programme Facebook page and Twitter account and received a total of 221 views during the course of the experiment. Tips were left for each undergraduate building on Foursquare detailing where the QR codes were placed and how to gain access to the Android application, an example of which is shown in Figure 29. User interaction online and on social media continued beyond the orientation week whereby the principal researched answered questions about the Android app on Twitter and the Boards.ie forum site.

3.8. Research Ethics

Under the Faculty of Science and Engineering Research Ethics Committee guidelines in the University of Limerick, all research activities involving the use of human beings participating in research activities must be reviewed and approved by the committee. Such approval was awarded for the research activities that form this thesis, in particular the conducting of email questionnaires and the gathering of anonymous usage data with the Android application for those users that consented to their information being captured and analysed. The email questionnaire information and consent sheet and the mobile app information and consent disclaimer screen that received approval can be seen in Appendix B.

3.9. Summary

This chapter describes the design, implementation and delivery of the three deductive experiments that are presented in this thesis. The content and delivery of the two online questionnaires are presented, along with a detailed description of the design, development and deployment of the mobile website and Android application. The results of the online questionnaires and the analysis of such is presented in chapter 5, along with the data gathered from the deployment of the mobile website and Android application coupled with the evaluation of this deployment. The mixed granularity indoor wayfinding functionality within the Android application, which is the key demonstrator of the theory of this thesis, is described in more detail in the next chapter.

4. Mixed Granularity Indoor Wayfinding

This chapter describes the theory of a pervasive approach to mixed granularity indoor wayfinding presented by this thesis, as exemplified using an Android smartphone application deployed as a deductive experiment among first year students in the University of Limerick. The basis for this theory is explored and the design, implementation and deployment of the indoor wayfinding functionality of the Android application are described.

4.1. Mixed Granularity Wayfinding

While describing the concept of city imageability, Lynch investigates the underlying factors and stimuli involved during the act of wayfinding in an unknown environment (Lynch, 1960). The formulation of a good mental image of an environment is described as the strategic link to successful wayfinding. It is suggested that the quality of a mental image can be improved by education, and specifically by the invention of a symbolic device that can teach people to be well orientated by describing the relationships between the main environmental features in a way which is sympathetic to image development. While many examples and solutions of using technology to assist in wayfinding exist, as described in chapter 2, this thesis attempts to apply the foundation wayfinding concepts as described and suggested by Lynch (1960) in a pervasive manner to the act of wayfinding within indoor environments. This application was made possible by the advances in pervasive computing, in particular the proliferation of smartphone devices among the population, as described in section 1.1.

During his investigation, Lynch also identifies emotional impact as a factor in successful wayfinding. He theorises that the ability of a person to form a good mental image of their environment is directly related to the person's sense of emotional security during wayfinding. Furthermore, the *"surprise"* and *"mystification"* enjoyed by a person during the exploration of an unknown environment is suggested as optimal under the following two conditions; firstly that the confusion or unknown elements must be limited to *"small regions in a visible whole"* (Lynch, 1960, p. 6), and secondly that over time the unknown elements can become familiar and no longer unknown. The results of experiments conducted also show that users become very uncomfortable when wayfinding in what they perceive as a void and need constant reassurance that they are not lost (Darken, et al., 2002). This thesis exemplifies a solution to maintaining the balance of mystification versus information delivery while wayfinding using a pervasive computing approach in the context of indoor wayfinding, by defining a mixed granularity mapping solution and deploying it using an Android application. This mixed granularity mapping system defines an indoor floor map, within the dimensions of a building, as a network of navigation nodes that store points of interest at each node and at connections between nodes in the network. The fine granularities of the building dimensions provide a fixed framework, or a *"visible whole"*, within which the user can explore the coarsely granular points of interest located between the navigation nodes, which act as *"small regions"* (Lynch, 1960, p. 6). As the user engages with the mixed granularity indoor wayfinding solution, it is expected that the level of familiarity the user has with the navigation nodes and points of interest will increase, allowing the user to learn how to wayfind successfully within the unknown indoor environment and thus allowing the environment to become increasingly known to the user.

During the discussion on building a mental image it is suggested that for wayfinding to be successful, the person should play an active role in the development of a mental image, and it should be flexible enough to be adapted to meet the requirement of multiple scenarios (Lynch, 1960). This thesis also attempts to implement this suggestion within the mixed granularity indoor wayfinding solution presented. The user was required to take an active role by using the smartphone application to explore navigation nodes on a floor map and discover where various points of interest are located in relation to those nodes, thus supporting the user in the creation of their mental image of the indoor environment. Furthermore, the use of QR codes within the mixed granularity scenario allowed the user to quickly re-orient themselves and change the context of focus from the coarsely granular points of interest to the finely granular positions of the QR codes on the floor map. By scanning the QR codes placed at the key navigation nodes (e.g. stairwells, entrances) using the Android application, the user can locate their precise position on a floor map and continue the act of wayfinding with a fixed point of reference. This feature, coupled with the points of interest filtering within the Android application, allowed the mixed granularity wayfinding solution to adapt in supporting multiple wayfinding scenarios and the changing mental image of the user.

A number of topographic elements that contribute to the mental image of a city are defined and described by Lynch (1960). This thesis attempts to use these physical elements, such as paths, nodes, districts and landmarks as components in definition of the mixed granularity floor maps, in an attempt to aid the user in the creation of their mental image while using the Android application and thus improving the indoor wayfinding experience. The way in which these topographic elements were deployed is described in section 5.3.2.

4.2. A Pervasive Computing Approach

The advancements in mobile technology development platforms such as Google Android and Apple iOS, coupled with the proliferation of smartphone devices among the population, in particular the 76% proliferation amount first year students during the time horizon of this deductive experiment (as described in section 5.1.1), has contributed to the smartphone ecosystem being a main part of the pervasive computing landscape (Cook, 2012). This landscape has enabled this thesis to implement, deploy and evaluate the mixed granularity indoor wayfinding solution as part of a deductive experiment. The definition of this mixed granularity indoor wayfinding solution was heavily influenced by the suggestions described by Lynch (1960). A number of these suggestions are conducive with the nature of pervasive computing, as described in section 3.1. One of these suggestions is that of a device or solution which aids the user in the creation of a mental image of their environment, thus improving the process of wayfinding. Another such suggestion is that the more active a role the user has in the use of such a device and how well the device adapts to the changing wayfinding requirements of the user impacts on the successfulness of the wayfinding process. This thesis uses the pervasive nature of a smartphone application and the widespread exposure of the population to smartphone interfaces to exemplify these suggestions and act as a foundation in the implementation of a mixed granularity indoor wayfinding solution.

In addition to the pervasive computing nature of a smartphone application, QR code technology was also part of the mixed granularity indoor wayfinding solution and was used as a bridge between the two levels of granularity within the indoor wayfinding solution, as well as a bridge between the physical world of the environment being explored and the virtual world of the environment's representation within the smartphone application. The use of QR codes further reinforced the suggestion that the person should play an active role in the development of their mental image during wayfinding to ease the process of mental image creation (Lynch, 1960).

4.3. Exemplification Via Experimentation

This thesis exemplifies a mixed granularity solution to indoor wayfinding which allowed a user to explore unknown areas of an environment within the framework of a defined floormap. The solution aided the user in the creation and alteration of their mental image of an indoor environment and its component points of interest, with the overall intention being that the user developed a sufficient mental image over time to allow wayfinding to take place without the need to reference the wayfinding solution. A pervasive computing approach was used to exemplify this mixed granularity indoor wayfinding solution using an Android smartphone application. Furthermore, to extend this exemplification, this thesis defines a deductive experiment to deploy this Android application in the field, capture usage analytics and analyse the results. The experiment involved deploying the mixed granularity indoor wayfinding functionality within the First Seven Weeks Android application among first year students in the University of Limerick during the first semester of the 2012/2013 academic year. The use case for the deployment of the wayfinding feature of the application was to help students find points of interest such as lecture halls and food outlets situated in the undergraduate buildings on the University of Limerick campus, in particular the Main Building. This deployment was made possible due to the collaboration research project between the IDC and CTL, looking at the extension of the First Seven Weeks Programme information through online delivery channels. The following sections describe the design, implementation, deployment and dissemination of the mixed granularity indoor wayfinding solution within the First Seven Weeks Android Application.

4.3.1. Requirements and Design

The development and deployment of the mixed granularity indoor wayfinding solution included a number of key requirements in two areas; the mixed granularity indoor wayfinding solution itself; and the deployment of this solution within the context of the First Seven Weeks Programme Android application. These requirements are detailed in the following sections.

4.3.1.1. Mapping Interface

The key requirement of the mapping interface was to display the mixed granularity floor maps in a format that allowed the user to easily interact with and filter the relevant wayfinding information. This required the definition of a map format to store and display the network of navigation nodes, the relevant points of interest, the position of the QR codes, and the relationship between each of these information entities and data structures. The mapping interface took advantage of the interface constructs available using a smartphone touch screen interface, such as touch gestures for panning and zooming the display and dropdown UI elements and modal popup windows to filter and display information. The available screen size and the ability to display a limited view of information were also taken into consideration. Features allowing the user to select two nodes or points of interest in the network and plot and display a navigation course between them were also included, as well as the ability to explore the points of interest located on or around each node.

4.3.1.2. Map Definition

The categorisation of elements in the physical environment is described by Lynch (1960) that aids the user in the creation of their mental image of the environment. The representation of wayfinding information using these elements was a key requirement in the creation of the map definition. The first and most fundamental of these elements are paths, defined as the channels through which people move through an environment. The second of these elements are nodes, which are points of navigational focus at the intersection of paths. The third type of elements employed in the floor map definition is districts, which were used to differentiate areas using differing characteristics. The fourth and final type of elements used within the floor map definition are landmarks, which signify special instances of other elements that aid in the orientation of the user during wayfinding. The definition of the floor maps used in this thesis incorporate the use of these wayfinding elements which aid the user in understanding, interacting and learning from the mapping interface during the process of wayfinding in an indoor environment.

4.3.1.3. Floor Map Creation

The successful implementation of the map definition was dependent on the required relevant floor map information being available. This floor map information must be created or translated from existing data and structured using the path, node, district and landmark elements described in the previous section. It is conceivable that because these elements are primarily based around navigation paths of the user, a dead reckoning solution could be employed which would allow the paths to be recorded and created as a user walked each route in real time, similar to those presented by Shin (2010) and Koulouriotis (2011). This solution would verify that each virtual path is an accurate representation of the physical path and aid in easier maintenance and updating of the map information. The resultant floor map must contain all relevant paths between nodes, as well as all the relevant points of interest defined or captured at and between nodes for each floor. Landmarks such as entry and exit points, points of interest such as rooms and lecture halls, as well as districts and sub-districts such as blocks and areas within buildings also need to be defined or captured for each floor.

4.3.1.4. QR Code Integration & Placement

The use of QR codes provided a bridge between the virtual world of the mapping interface and the physical world of the indoor environment. Using the Android application, the user could scan a QR code to view the location of the QR code on the floor map, and thus their current location, denoted by a white node as seen in Figure 20. The QR codes also provided a bridge between the coarsely granular nature of the floor map definitions and the finely granular nature of the building dimensions, as represented using the mapping interface. By their nature, each QR code must be unique and generated according to where there are to be placed within each building, primarily in the main stairwells on each floor of the Main Building of the University of Limerick but also within the entrances of the other undergraduate buildings.

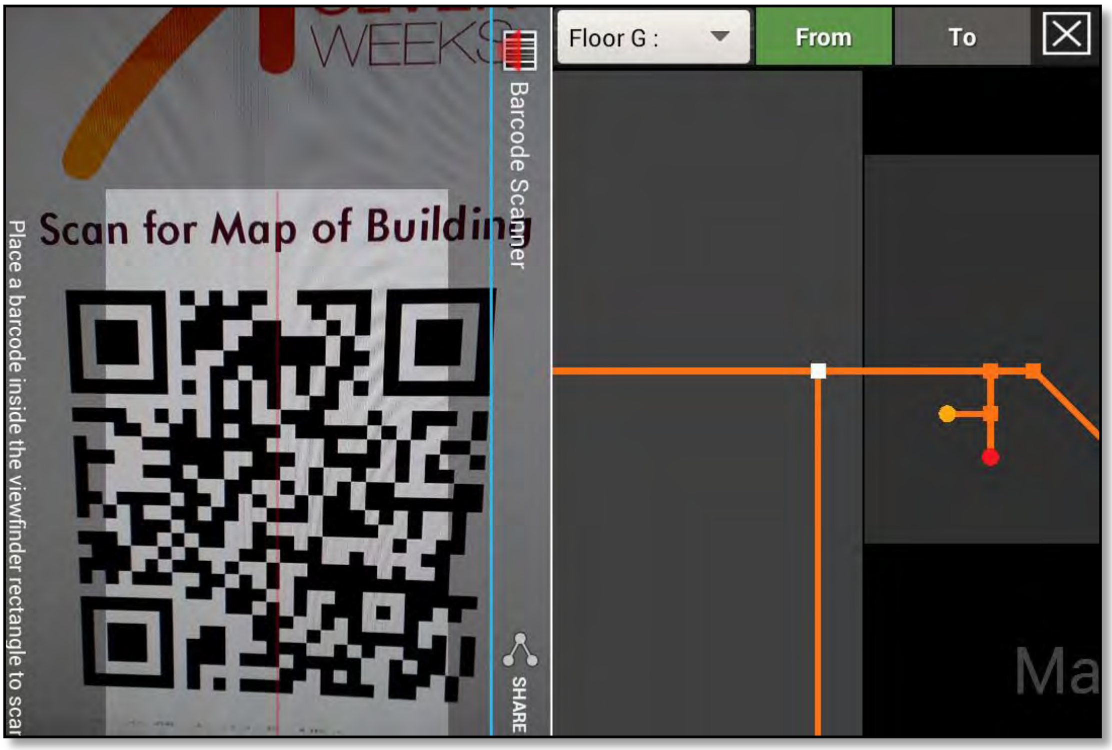


Figure 20. QR Scanning & Location Display

4.3.1.5. User Interaction Tracking

The Android application developed forms part of a second deductive experiment presented by this thesis as introduced in section 1.8.4. The structure of this experiment involved the deployment of the Android application and the analysis of observational data collected from the application and from the second student questionnaire. Therefore, the collection of observational data was a key requirement to the software development of the Android application. A method of tracking user interaction with the Android application and more importantly, with the mapping interface within the application, was a key requirement. This method must also allow profiling of the behaviour of each user over time.

4.3.2. Implementation

4.3.2.1. Mapping Interface

The definition of the floor map structure was centred on the use of the physical element categories described previously (paths, nodes, districts and landmarks) and mapping them into the virtual space to be displayed within the mapping interface of the Android application. This thesis utilises paths as the core element of the map definition. Each floor map was defined as a set of paths within the confines of the building dimensions, but not necessarily mapping exactly to the physical spaces and thoroughfares within the building. Paths were used in the floor map definition to denote a line of motion to the user, which according to Lynch (1960) should have clarity of direction. This clarity and simplicity was required in order to reduce the cognitive overhead required when the user needed to analyse and remember any series of successive navigation turns and twists, and also in the formation of a mental image of the environment. The paths within the map definition were designed to be as direct as possible in order to reduce this cognitive overhead, balanced with their directness not being counter-intuitive to the physical structure of the indoor environment. For example, in a large hall with multiple entry and exit points, the most direct and least amount of paths was defined along which the user can travel from and to each entrance/exit point. This method did not take into account any temporary configurations such as desks or partitions within the environment, but was instead intended to represent the general direction in which a user must travel to get to a navigation junction point (node). This method also contributed to the coarsely granular nature of the mapping interface, and thus reinforced the requirement of the mystification experience of wayfinding as described in section 4.1. An illustration of this method is presented in Figure 21, which compares the original architectural floormap of the hall EGO10 in the Main building of the University of Limerick (left of figure) with the coarsely granular navigation path representation of EG010 defined in the mapping interface (right of figure).

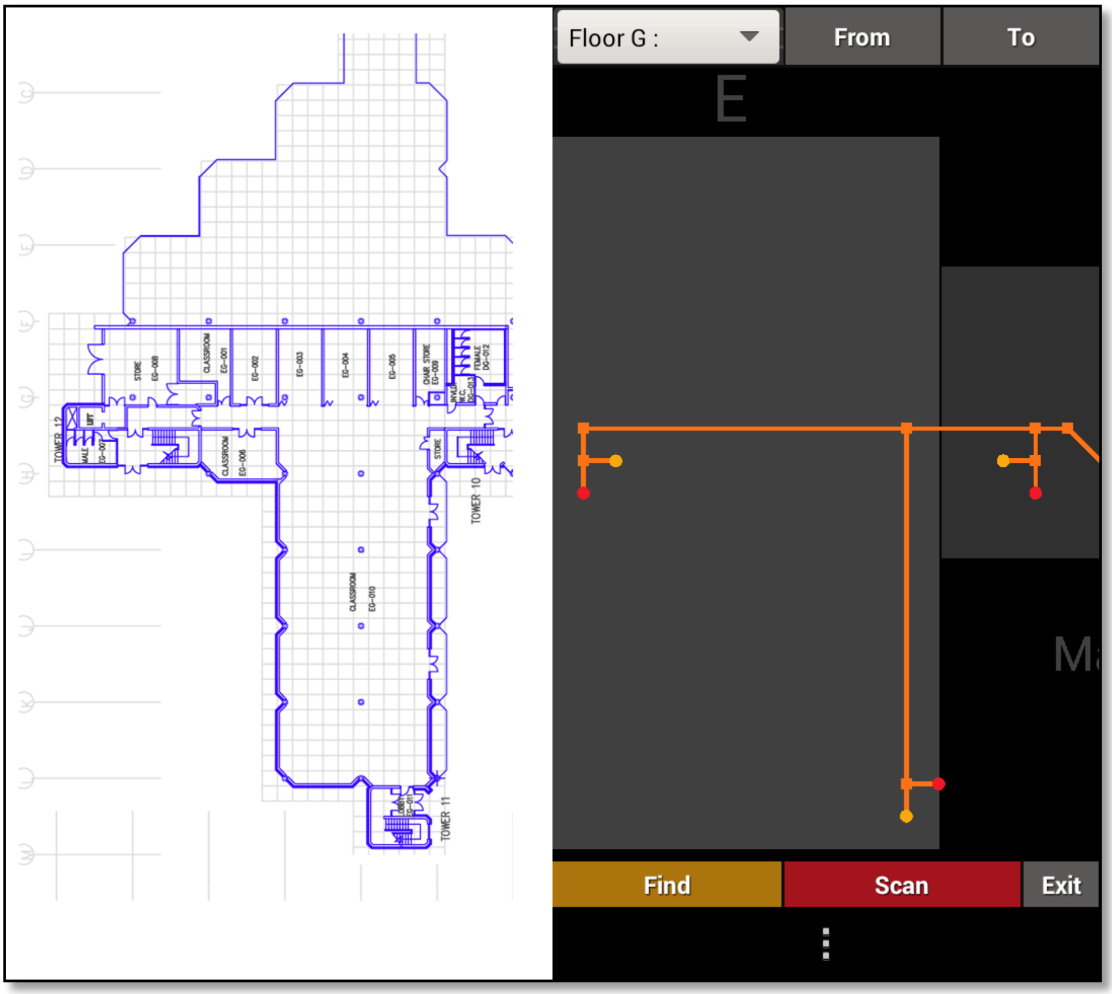


Figure 21. Coarsely Granular Navigation Paths

At the intersection of each path within the floor map definition, a node was placed to signify a navigation juncture. These navigation junctures are of compelling importance during the act of wayfinding (Lynch, 1960, p. 106) because of the requirement of the user to make navigation decision at the intersections of paths. The floor map definition utilised these navigation nodes to access the wayfinding information relative to the node and each path that intersects at that node. Within the Android application, tapping any node allowed the user to explore the points of interests located at that mode, or between that node and any neighbouring node, i.e. points of interest located along sections of a path. This information was displayed and accessed using an azimuth style arrow selector modal popup (Figure 13), which was displayed when a node was selected by the user and allowed the user to select a cardinal or ordinal direction around a node to view a list of points of interest. This exploration method not only aided the user in the creation of their mental image of the environment, but it also reinforced the mystification experience by presenting to the user coarsely granular information about points of interest in an area of the environment, e.g. in a specific corridor. This method of information display also required the user to explore the small region between navigation points to pinpoint the location of the required point of interest, thus reinforcing the goal that the Android application be used as a tool to allow the user to become familiar with the environment over time. The mapping interface also included multiple ways of accessing the points of interest information relevant to the current building and current floor being viewed by the user in the mapping interface. Using the Find button, the user could view a list of all the points of interest in the current building and filter these by type, such as Lecture Halls, Classrooms, Labs, Workshops, Food Outlets, Male Toilets, Female Toilets, Accessible Toilets, Stairs, Lifts, Entrances/Exits, Offices, Rooms and Halls (as shown in Figure 15). Selecting a point of interest from the list highlighted the node or path where that point of interest was located on the mapping interface. The plotting of wayfinding routes between nodes and points of interest was a feature that was also available to the user through the mapping interface. Using the To and From buttons within the mapping interface allowed the user to select a start and destination point of interest on the current floormap. The mapping interface then highlighted a route between these two points. The user could also set any node within the current floormap as a route start and/or end point by tapping that node in the mapping interface and select the To Here or From here options. An illustration of this route planning feature can be seen in Figure 14. The route planning algorithm used to navigate the mapping interface data structures and produce the shortest path between two nodes is Dijkstra's Algorithm (Dijkstra, 1959) and was implemented in the RouteFinder class in the RouteFinder.java file, included in Appendix F.

Districts are used to define areas within a floor map that are distinct and identifiable based on a range of differing physical characteristics such as design, form or symbol. Districts can further be segmented using sub-districts which may confirm to the parent district but are individually distinguishable. The concept of districts within the Android application was reinforced by and replicates the natural segmentation of the undergraduate buildings within the University of Limerick at a campus wide level but also internally within each building, particularly within the Main Building which is segmented into districts called blocks.

Within the mapping interface, each map was a representation of one floor of the building, with a dropdown list interface element allowing the user to select different floors to view. A number of node types were defined based on the activity classifications (Gusenbauer, et al., 2010); specifically the ascending and descending stairs and travelling up and down elevator activities. Entrance and exit nodes were treated as landmarks within the mapping interface and were highlighted using different colour nodes (red). Stairwell and elevator landmarks nodes were also highlighted (in yellow) and provided the user with Up and Down navigation buttons allowing the user to virtually traverse between floors. The concept of districts can also be extended to encompass this floor level implementation within the mapping interface because each floor was designated with a watermark on the presented floor map as well as the floor level being displayed as the selected option in the floor selector dropdown list. The mapping interface automatically presented the relevant entry level floor by default when a building was selected for viewing by the user, e.g. many buildings have floors below the one which contains the main entrance.

4.3.2.2. Floor Map Definition and Creation

The translation of the existing physical indoor environment of the undergraduate buildings in the University of Limerick into the required map definition and structure as described in the previous section presented a signification challenge within this thesis. Firstly, various file formats were created to define the information to be displayed on each floor map. Secondly, the process of creating a floor map using this definition for each floor of each undergraduate building was addressed.

4.3.2.2.1. Floor Map File Format

The JSON format was chosen as the file format to encode the various pieces of information needed in the floor map definition because of its lightweight nature, allowing for any updates to the floor map files to be downloaded easily from the Drupal CMS JSON REST webservices, as described in section 3.5.3.6.3. A graph structure inspired by graph structure presented by Goetz and Zipf (2011) was defined within a file for each floor of each building, with the filename structure BuildingID_FloorNumber.txt used to differentiate each file. Within the file a JSON structure was defined which includes the ID of the building, the version of the file, the date and time when the file was last updated, the main label watermark to be displayed in the mapping interface, the list of nodes, the building dimensions (drawn as background shapes on the mapping interface) and any text labels that are to be displayed to the user. Each node is defined in the list of nodes with an ID, a type, x, y, and z co-ordinates, a list of the nodes located in the N, NE, E, SE, S, SW, W and NW directions around the node, a flag to denote if traversal up or down can be made from the node to other floors (e.g. stairwell or elevator nodes), the direction at which a user can enter and exit the node if it is an entrance/exit node and a list of room IDs located in the N, NE, E, SE, S, SW, W and NW directions around the node. The dimensions of the building were defined as background shapes in a list within the file. Each shape was defined with an ID, a shape type, two sets of x and y co-ordinates, a radius value and a background colour value. These background shapes were used to define districts elements within the floor map of the main building of the University of Limerick. This building is physically divided into five blocks, A to E, which translated into district map elements as described in section 5.3.2.1 and were drawn as background rectangles on the floor map, distinguished using alternating shades of background colours and text labels, as shown in Figure 22. This shape implementation reinforced the mystification concept described in section 5.2 by defining the outer dimensions of the physical building as the “visible whole” within which the user can explore. The text labels to be drawn on the mapping interface were defined within the file as a list containing a label ID, x and y co-ordinates, a text string value, a font size value and a background colour value.

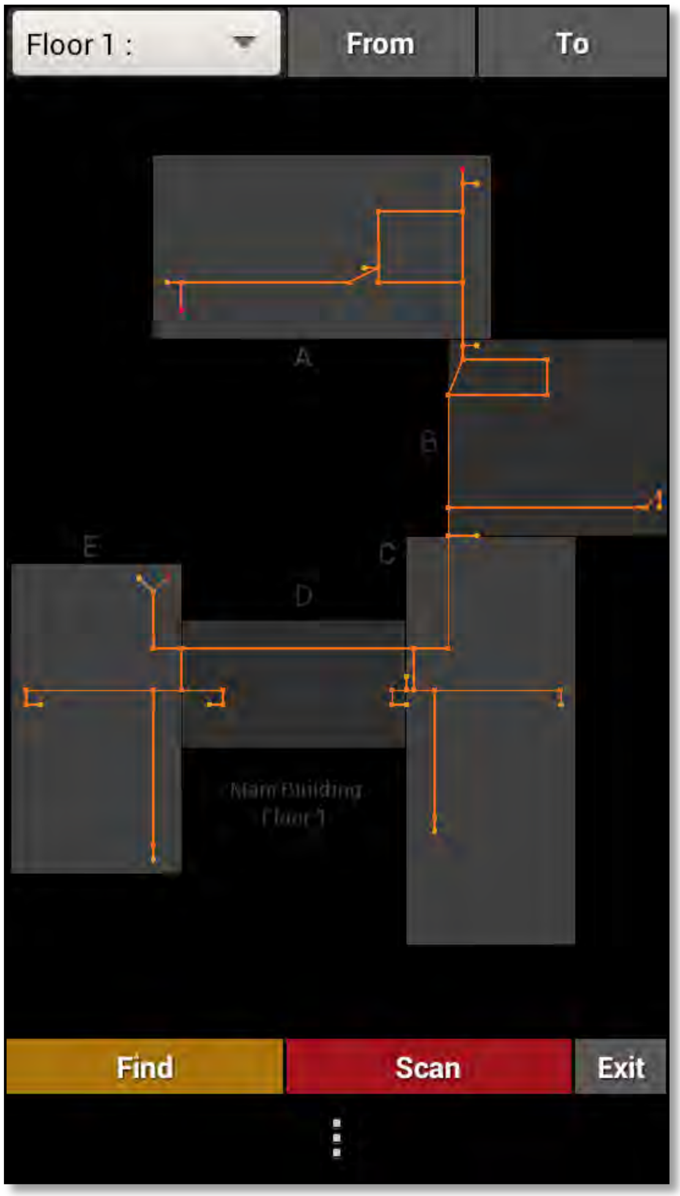


Figure 22. District Representation Using Alternate Backgrounds

The JSON floormap file format is shown in Figure 23 and includes descriptive comments for each field and an example file can be found in Appendix D.1.

```
{"map": {
        "i": "[0-9]+",  //map ID
        "v": "[0-9]+", //version number
        "d":"yymmddhhmm", //date & time last updated
        "m":"[a-zA-Z0-9]+", //main label watermark string
        "n":[ { //list of nodes
                "i":"[0-9]+", //Node ID
                "t":"[1|2|3|4|5|6|7]", //Node Type
        [Entrance_Exit|Doorway|Stairwell|Lift|Mappoint|Midnode|Tunnell]
                "x":"[0-9]+", //x coordinate, based on main entrance at 0,0
                "y":"[0-9]+", //y coordinate, based on main entrance at 0,0
                "z":"[0-9]+", //z coordinate, not currently used
                "n1":"[0-9]*", //ID of node at direction N
                "n2":"[0-9]*", //ID of node at direction NE
                "n3":"[0-9]*", //ID of node at direction E
                "n4":"[0-9]*", //ID of node at direction SE
                "n5":"[0-9]*", //ID of node at direction S
                "n6":"[0-9]*", //ID of node at direction SW
                "n7":"[0-9]*", //ID of node at direction W
                "n8":"[0-9]*", //ID of node at direction NW
                "en":"[0-9]*", //direction at which the user can enter this node
                 "ex":"[0-9]*", //direction at which the user can exit  this node
                "u":"[1]*", //flag denoting if traversal upwards from this node is possible
                 "d":"[1]*", //flag denoting if traversal downwards from this node is possible
                "r1":"[[0-9]*,]*", //list of room IDs located at direction N
                "r2":"[[0-9]*,]*", //list of room IDs located at direction NE
                "r3":"[[0-9]*,]*", //list of room IDs located at direction E
                "r4":"[[0-9]*,]*", //list of room IDs located at direction SE
                "r5":"[[0-9]*,]*", //list of room IDs located at direction S
                "r6":"[[0-9]*,]*", //list of room IDs located at direction SW
                "r7":"[[0-9]*,]*", //list of room IDs located at direction W
                "r8":"[[0-9]*,]*", //list of room IDs located at direction NW
                "r9":"[[0-9]*,]*" //list of room IDs located at this node
        }*,
        "s":[{ //list of background shapes, used to define building dimensions/districts
                "i": "[0-9]+",  //background ID
                "t": "[1|2]+", //shape type [RECTANGLE|CIRCLE]
                "x1": "[0-9]+", //first x coordinate of shape
                "y1": "[0-9]+", //first y coordinate of shape
                "x2": "[0-9]*", //second x coordinate of shape
                "y2": "[0-9]*", //second y coordinate of shape
                "r": "[0-9]*", //radius of circle shape
                "c": "[#[a-f|A-F|0-9]{6}]*" //background colour of shape
        }*,
        "t":[{ //list of text labels
                "i": "[0-9]+",  //label ID
                 "x": "[0-9]+", //x coordinate of label
                "y": "[0-9]+", // y coordinate of label
                "t":"[a-zA-Z0-9]+", //label text
                "s": "[0-9]+", //font size of text
                 "c": "[#[a-f|A-F|0-9]{6}]*" // colour of text
        }*
]}
```

Figure 23. JSON Floormap File Definition

This thesis defines two other file types that accompany the floor map definition file as part of the structured data used to create the mapping interface. An index of all the rooms located on each floor of each building was defined in the room list JSON file. This file was defined for each floor of each building, with the filename structure r_BuildingID_FloorNumber.txt used to differentiate each file. Within the file a JSON structure was defined which includes the version of the file, the date and time when the file was last updated, the description of the building and floor that this file relates to and a list of rooms. Each room was defined in the list of rooms with an ID, a type, a room number and a description. The JSON roomlist file format is defined in Figure 24 and includes descriptive comments for each field and an example file can be found in Appendix D.2.

```
{"room": {
        "i": "[0-9]+",  //file ID, not currently used
        "v": "[0-9]+", //version number
        "d":"yymmddhhmm", //date & time last updated
        "m":"[a-zA-Z0-9]+", //building and floor description
        "r":[ { //list of rooms
                "i":"[0-9]+", //Room ID
                "t":"[1|2|3|4|5|6|7|8|9|10|11|12|13|14|15|16]", //Room Type
        [ROOM|TOILET_MALE|TOILET_FEMALE|TOILET_DISABLED|TOILET_BOTH|TOILET_ALL|OFF
        ICE|CLASSROOM|LECTUREHALL|LAB|FOOD|HALL|WORKSHOP|ENTRANCE_EXIT|LIFT|STAI
        RWELL]
                "te":"[a-zA-Z0-9]*", //room number/designation
                "d":"[a-zA-Z0-9]*", //room description
        }*
]}
```

Figure 24. JSON Roomlist File Definition

The third file defined by this thesis as part of the mapping interface data structures was the QR code list file, which contains the list and location of all the QR codes within the mapping interface. Only one of these files existed, with the filename structure qrcodes.txt. Within the file a JSON structure was defined which includes the version of the file, the date and time when the file was last updated the description of the file and a list of QR codes. Each QR code is defined in the list of QR codes with an ID, a node ID, map ID and floor ID within which the QR code is located. The JSON QR code list file format is defined in Figure 25 and includes descriptive comments for each field and an example file can be found in Appendix D.3.

```
{"codes": {
        "i": "[0-9]+",  //file ID, not currently used
        "v": "[0-9]+", //version number
        "d":"yymmddhhmm", //date & time last updated
        "m":"[a-zA-Z0-9]+", //file description
        "n":[ { //list of codes
                "qr":"[0-9]+", //QR Code ID
                "n":"[0-9]+", //Node ID where QR is located
                "m":"[0-9]+", //Map ID where QR is located
                "l":"[0-9]+", //Level ID where QR is located
        }*
]}
```

Figure 25. QR Code List File Definition

Within the android application, when a user selected a building to view from the menu, the relevant floor map definition file was loaded and parsed into a series of hashmap data structures which were used to store lists of the node, room, shape, text and path data objects along with their ids to provide faster lookup operations. These data structures were represented as classes within the code of the Android application and the ones in question, F7WMap_Tree, F7WMap_Node, F7WMap_Room, F7WMap_Shape and F7WMap_Text can be seen in Appendix D.4. Using the Android Graphics library[40], the network of paths, nodes, districts and landmarks were painted onto the screen canvas using these hashmap data structures.

[40] Android Graphics Library: http://developer.android.com/reference/android/graphics/package-summary.html

Highlighted paths and nodes were redrawn depending on the interaction of the user. For example, when plotting a route between two nodes, the highlighted path was redrawn on the canvas in a separate colour to display the wayfinding path to the user, as shown in Figure 14. When a user selected a node on the mapping interface, the room and node mapping data structures were parsed to display the list of rooms located at that node or located in one of the eight cardinal and ordinal directions surrounding that node, as shown in Figure 13. The various lookup and redraw functions generated from the parsed file data and stored in the hash map data structures are the core to how the mapping interface displayed the information to the user within the Android application. This vector based system allowed for panning and zooming of the screen canvas using the touch based interface gestures of a smartphone, without the loss of image quality and also provides flexibility when maintaining and updating the mapping data. The android application polled the Drupal CMS webservice for any updates to the mapping files and when a change was detected, the new mapping JSON files were downloaded by the application. This allowed updates to mapping information to be made without the need to publish a new version of the Android application to the Google Play Store. The check for new map data was done automatically when the application was run. It could also be initiated manually by the user using the Refresh command in the mapping interface menu.

4.3.2.2.2. Footstep Detection

It is envisaged that a dead reckoning solution which uses footstep detection could be used to record the path walked by a user using a separate Android application. This application would subsequently translate that path, along with specified navigation turns and points of interest entered manually and captured during the recording process, into the required floor map definition. This thesis formulates a design for an Android application that allows a user to walk a path and record points of interest and navigation turns while walking. The implementation of this second Android application began with footstep detection and the choice of algorithm used to detect footsteps using the inbuilt smartphone gyroscope. A threshold algorithm similar to the algorithm implemented by Koulouriotis (2011), which detects the different states of a step based on the frequency data and its relation to relevant thresholds, was chosen because of the simplicity in the implementation of this method. However, early testing of the implementation of this footstep detection method within the second Android application produced a footstep detection error rate of approximately 20% to 25%. As a result, it was decided to put the development of the footstep detection feature on hold. This allowed for the prioritisation of the implementation of the main Android application and the mixed granularity mapping interface. As a result of this re-prioritisation, the second Android application that automates the creation of the floor map definition file was out of scope of this thesis. This solution remains as a possible item of future work however similar solutions are already in existence (Shin, et al., 2012).

4.3.2.2.3. Floor Map Translation

Due to the re-prioritisation of implementation features, the footstep detection Android application was out of the scope of this thesis. As a result, an alternative method was needed to capture and translate the relevant map information for the ten undergraduate buildings included in the mapping interface. Through collaboration with the Buildings and Estates Department in the University of Limerick, access was provided to the architectural floor map files, in PDF format, of the ten undergraduate buildings. Using Microsoft Visio, the required paths, nodes, landmarks and districts were drawn on an overlay of the architectural floor maps manually using domain knowledge of the indoor environment of the ten buildings. This overlay method allowed for grid co-ordinates to be defined for each element of the floor map and entered into the relevant JSON definition file. An illustration of this overlay method is presented in Figure 26, which shows the manually defined navigation points in the left of the figure, compared with the display of the navigation nodes within the mapping interface for the same location in the right of the figure.

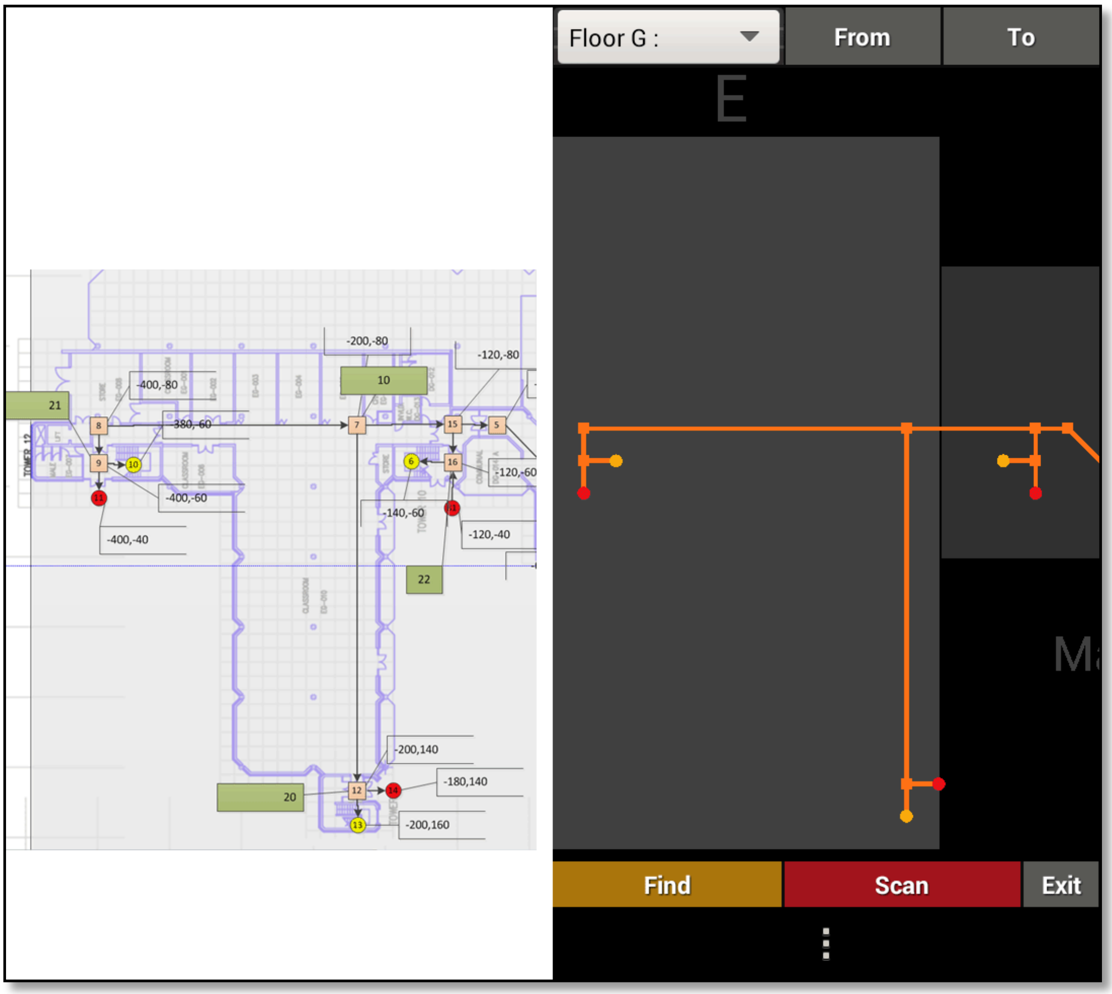


Figure 26. Floormap Translation Overlay Method

The collaboration with the Buildings and Estates department also allowed for the printed QR codes to be placed within the ten undergraduate buildings on campus.

4.3.2.3. QR Codes

QR codes are employed for three purposes within this thesis. Firstly, they provided a method of marketing and dissemination of Android application and mobile website. Secondly, they provided a mechanism for smartphone users to access the mobile website and continue via a Google Play Store link to download the Android application. Thirdly, they allowed users of the mapping interface to pinpoint their location on a floor map thus allowing reorientation during wayfinding. The placement of the QR codes was agreed as part of the collaboration with the Buildings and Estates department. QR codes were integrated with existing signage in the stairwells of the Main Building, as shown in Figure 11, which is one of the largest on campus and has a reputation as being confusing to navigate. This building is constructed around thirteen towers which house the stairwells and most entrance/exit points, meaning the QR codes are placed in many of the main navigation juncture points within the building. A QR code was placed within or near the entrance of the nine other undergraduate buildings on campus, which are listed in Figure 27 below.

Undergraduate Buildings	Map ID
Computer Science and Information Systems (CSIS)	1
Schuman	2
Kemmy Business School (KBS)	3
Glucksman Library	4
Foundation	5
Engineering Research Building (ERB)	6
Languages	7
Physical Education and Sports Science (PESS)	8
Schrodinger	9
Main	10

Figure 27. Undergraduate Buildings with Floormaps

Each QR code was generated as a code that represents a unique URL structured as http://first7weeks.ul.ie/download.html?qrid=XX, where XX is the unique ID of the QR code stored in the QR code list definition file. By scanning the QR code with a smartphone QR code scanner application, the user can navigate to the First Seven Weeks mobile website, http://first7weeks.ul.ie. This URL on the ul.ie domain was created in collaboration with the Information Technology Division (ITD) in the University of Limerick. By scanning the QR code with the Android application, the unique QR code ID is parsed from the URL of the QR code scanned and displayed as a highlighted node on the mapping interface. Within the Android application, a Scan QR Code menu item was placed on the home screen for quick access, as well as a Scan button located within the mapping interface. Each of the unique QR codes was generated using the free QR code generator on the Kaywa website[41]. These generated codes were then printed on A4 posters with a description of the QR code and instructions on how to use it. An example QR code poster is included in Appendix E.

4.3.2.4. User Interaction Logging

In order to collect observational data that forms part of the second deductive experiment performed by this thesis, a method to track and collect user interaction with the Android application was needed. Two methods of interaction logging were included in the Android application. Firstly, Google Analytics for Mobile[42] v.1.4.2 was used to record and collect user analytics data from the Android application. Page

---

[41] Kaywa Website QR Code Generator: http://qrcode.kaywa.com

[42] Google Analytics for Mobile: http://www.google.ie/analytics/mobile/

view details based on the each of the application's activities were tracked, along with the device type and operating system version. An Android application is segmented into activities which at an abstract level can represent each screen. Within the Android application for example, the F7W_BuildingList_Activity renders the building menu and processes all interactions related to that screen. The Google Analytics for Mobile library also allows custom events to be defined and triggered programmatically from the Android application. This allows for a finer granularity of data tracking based on events segmented by categories, actions and labels. Within the Android application, custom events were used to track the user interactions with the mapping interface, logging the actions on each floor and map such as node information access, points of interest information access, route planning and map floor traversal. This analytics data is presented in next chapter. All of the analytical data collected by the Google Analytics for Mobile library was transmitted from the Android application to the Google servers while the application was running and connected to the internet, where it was aggregated and anonymised for reporting purposes. As a result of this anonymisation and aggregation, it was not possible to profile a particular user or a single smartphone device to track and analyse a sequence of interaction in chronological order. A second logging mechanism was included in the Android application to allow the capture of this information. Coupled with the implementation of the Google Analytics custom events, the logging mechanism recorded each of the interactions and includes a date stamp and unique device ID. This data was transmitted to the First Seven Weeks Drupal CMS when the application was run and an internet connection was available. This device based logging data was only collected on devices where the user opted in to the research disclaimer as described in section 4.5.3.3. The collected data allowed for the analysis of user behaviour based on how and in what sequence the different features of the mapping interface were used. The results of this analysis are presented in the next chapter.

4.3.2.5. Help Screen

The success of this deductive experiment was dependent on capturing user interaction data from the mapping interface of the Android application, which in turn was dependent the effective use of the mapping interface by the user. To aid the user in the use of the mapping interface, a help screen was included which was displayed when the mapping interface was opened the first two times. It could also be accessed at any time using the Help option in the mapping interface menu. This help screen, shown in Figure 28, displayed a short description of each of the features of the mapping interface as accessed by the user using the interface buttons.

Figure 28. Map Help Screen

4.3.3. Deployment & Dissemination

The mixed granularity indoor wayfinding solution was deployed within the First Seven Weeks Android application among first year students in the University of Limerick over a two year period. The dissemination of the Android application, and by inference the wayfinding features of the application, was primarily conducted via the placement of the QR code posters within the undergraduate buildings on campus in the University of Limerick. The description contained on each poster, as shown in Appendix E, includes a reference to the wayfinding features of the application.

Further dissemination of the mixed granularity indoor wayfinding solution was conducted using social media. Tips were created for many of the undergraduate building on Foursquare[43]; the location based social network application. These tips, an example of which is shown in Figure 29, are accessible when users check-in to any of the undergraduate buildings using the Foursquare application and include a description of the QR codes and how they can be used to download the First Seven Weeks Android app to access the wayfinding features of the app.

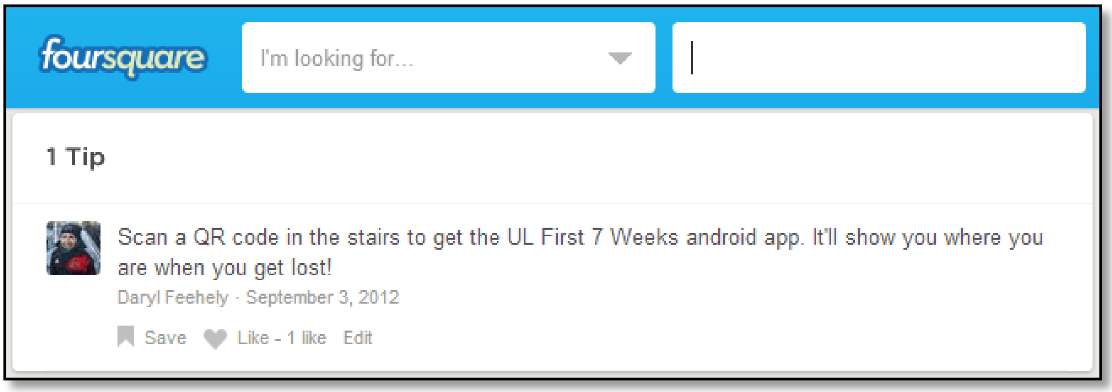


Figure 29. Foursquare Tip

The social media micro-blogging site Twitter[44] was also used to disseminate the wayfinding features of the Android application. Direct engagement with students asking location questions about the undergraduate buildings on Twitter offered the opportunity to disseminate the wayfinding features of the Android application. Evidence of the effective dissemination of the application was also discovered on Twitter when independent observations of the wayfinding features of the application in use were posted as comments, as shown in Figure 30.

---

[43] Foursquare –http://www.foursquare.com

[44] Twitter – http://www.twitter.com

Figure 30. Twitter Dissemination Observation

4.4.Summary

This chapter describes the design, development and deployment of the mixed granularity indoor wayfinding solution within the First Seven Weeks Android application. The mixed granularity concept of the mapping interface is described along with its origin and inspiration from the wayfinding suggestions of (Lynch, 1960). The exemplification of the solution within the Android application as a deductive experiment is detailed including the way in which usage analytics and observational data is gathered. The results of this data analysis along with the results of the other questionnaire based deductive experiments conducted by this thesis are presented in the next chapter.

5. Experimentation & Evaluation (Data Analysis)

This chapter presents the results of the three deductive experiments conducted by this thesis. The results of both student questionnaires are included, along with the usage and analytics data gathered from the Android smartphone application and mobile website. The three sets of observational data are analysed in the context of producing a grounded theory in answer to the research question posed by this thesis.

5.1. The First Questionnaire

As described in section 3.4.1, the first deductive experiment conducted in this thesis is a questionnaire among first year students in the University of Limerick during April/May 2012. The questionnaire was circulated via email and is included in Appendix A.3.

5.1.1. Results & Findings

The total number of questionnaire respondents aged over 18 years of age was 188. The relevant data collected was restricted to participants over the age of 18 in accordance with the research ethics guidelines as described in section 3.8. 179 of the respondents were first year students, which was the eligible cohort this experiment aims to analyse. With the total number of registered first year students for the 2011/12 academic year at 2450, the questionnaire yields a response rate of 7.3%, which was treated by this thesis as a representative sample of the first year undergraduate population of the University of Limerick. The results were collected in the format of a CSV export from the online Survey Monkey[45] questionnaire. Any categorical descriptive data within the result set were then recoded as numerical values for analysis using the IBM SPSS[46] statistical analysis software package. An example of this is the recoding of all of the Likert scale question results, which were stored using their text description in the Survey Monkey export data set and were recoded as 1-5 numerical values to represent the five point Likert scale. IBM SPSS was then used to determine frequency statistics for all questions and correlation statistics for a subset of question pairs. Full results to each question are presented in Appendix A.3.

5.1.1.1. Respondent Study Discipline

Among this population, as shown in Figure 31, 20.7% studied in the discipline of Arts, Humanities and Social Sciences, 20.1% in Engineering, 19% in Science, 14.5% in Business 10.6% in Health Science, 10.6% in Education and 4.5% in other disciplines.

---

[45] Survey Monkey: http://www.surveymonkey.com

[46] IBM SPSS: http://www-01.ibm.com/software/analytics/spss/

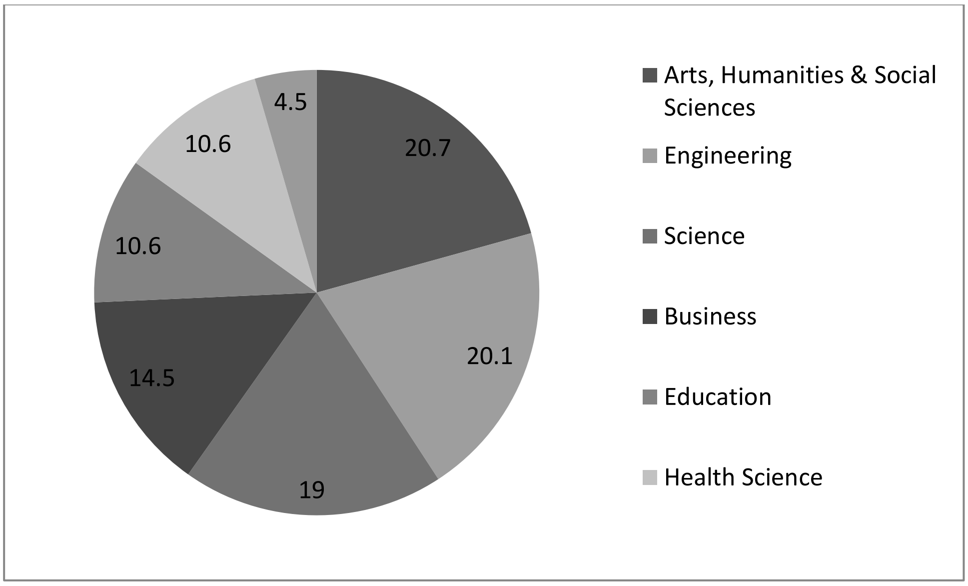


Figure 31. First Questionnaire - Respondent Study Discipline

The relationship between smartphone ownership and study discipline was analysed using a significance test. The null hypothesis that there was no relationship between study discipline and smartphone ownership was accepted based on the results of a Chi-Square test and a Cramer's V association measure, which resulted in a chi-square value of 3.35 with 6 degrees of freedom where p is 0.764, showing no significance. The Cramer's V value of 0.137 showed a positive association however at the insignificant 0.764 level. These results are presented in Figure 32.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app) * In which discipline are you studying?	179	100.0%	0	.0%	179	100.0%

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.137			.764
	Cramer's V	.137			.764
Interval by Interval	Pearson's R	.015	.075	.195	.846[c]
Ordinal by Ordinal	Spearman Correlation	.016	.076	.210	.834[c]
N of Valid Cases		179			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Based on normal approximation.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.349[a]	6	.764
Likelihood Ratio	3.719	6	.715
Linear-by-Linear Association	.038	1	.845
N of Valid Cases	179		

a. 3 cells (21.4%) have expected count less than 5. The minimum expected count is 1.88.

Figure 32. First Questionnaire - Smartphone Ownership Vs Study Discipline Significance Testing

5.1.1.2. Smartphone Penetration & Landscape

The results of the first questionnaire show that 76.5% of first year students had a smartphone. This percentage was higher than the previously stated Mobile Planet penetration figure of 72% for 18-29 year olds[47]. The Google Android operating

[47] Mobile Planet Survey Result, http://www.thinkwithgoogle.com/mobileplanet

system was shown to be the most prevalent smartphone platform with 46% of the respondents owning Android phones, as shown in Figure 33. This result confirms the first of the two sub-hypothesis presented as part of this first deductive experiment in section 1.8.4, that Google Android was the best development platform on which to deploy the smartphone application because it was the most prevalent among first year students. Second to Android, 32.8% of respondents' smartphones were Apple iPhones. This high percentage led to the decision to include a mobile website as part of the second deductive experiment, the development and deployment of the First Seven Weeks Android application and mobile website as described in section 3.5. The deployment of a mobile website to accompany the Android application deployed in the second experiment allowed the First Seven Weeks programme content to be disseminated to users with iPhones.

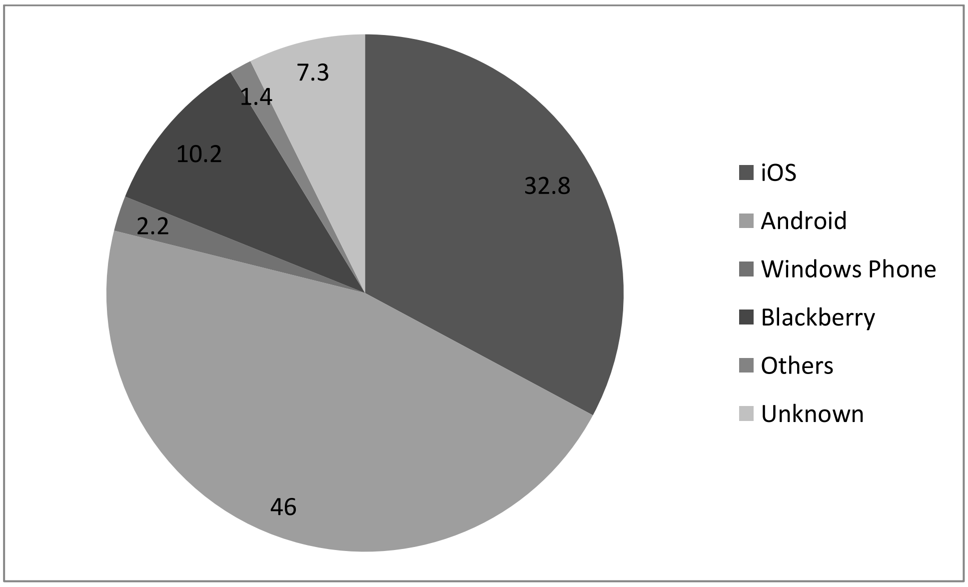


Figure 33. First Questionnaire - Smartphone Operating System

Other headline results regarding the smartphone landscape among first year students show that among Android users, v2.3 Gingerbread was the most prevalent operating system (21.1%) and among iPhone users, iOS v5.x was the most prevalent operating system (55.6%). The results also showed that the majority of respondents (71.9%) were engaged on pre-pay contracts with their mobile phone network operator. 37% of respondents with a smartphone intended on getting a new smartphone within the next year and 31% of those without a smartphone also intended on getting one within a year.

5.1.1.3. Feature Usage & Importance

With regard to smartphone feature usage, accessing Social Networks was shown as the dominant feature used daily with 67.9% of respondents using this feature daily (one or more times per day) , followed by Web Browsing at 63.5% daily usage, as detailed in Figure 34.

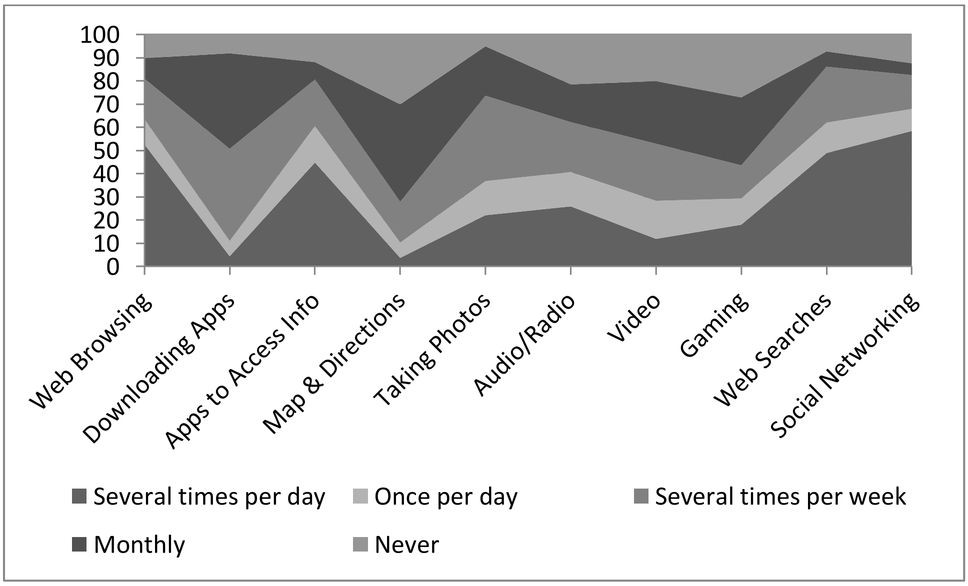


Figure 34. First Questionnaire - Smartphone Feature Usage

In terms of feature importance however, Taking Photos was shown as the most important with a 52.4% positive importance rating (very important and important).

Web Browsing also resulted in a 52.4% importance rating, however Taking Photos was deemed very important by 28.6% of the respondents whereas 26.2% rate Web Browsing as very important, as shown in Figure 35.

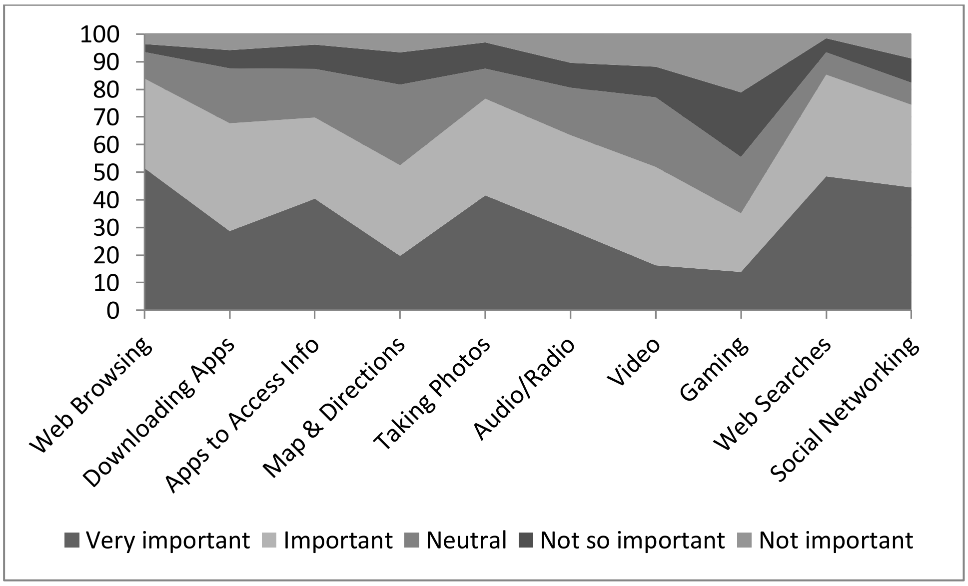


Figure 35. First Questionnaire - Smartphone Feature Importance

5.1.1.3.1. Maps & Directions Feature Importance

In the context of the second sub-hypothesis presented in section 1.8.4, that Mapping and directions are useful types of campus information to deliver using a smartphone device, the results confirming or refuting this hypothesis are somewhat open to interpretation. The results showed that daily usage of mapping and directions features are low at 10.3% and that 30.1% of respondents never used this feature. In contrast however, monthly usage of this feature (once or more times daily, several times per week and once per month) stood at 45.6%. The importance rating for mapping and directions showed a 2.87:1 ratio of positive against negative importance ratings along with a 29.2% neutral importance rating. One possible reason for the high percentage of 'Never Use' respondents and neutral importance rating was that a smartphone mapping and directions solution for the University of Limerick did not exist prior to deployment of the application as part of this thesis. When asked what was the likeliness of using a smartphone app for campus directions if one were available, 74.9% responded with positive likeliness (likely and very likely). Only two other possible smartphone application features yielded more positive likeliness ratings than campus directions. These features were Entertainment and Social Info (76.9%) and Offers and Deals info (75.1), as shown in Figure 36, however Campus Directions was the highest rated Very Likely feature (49.1%).

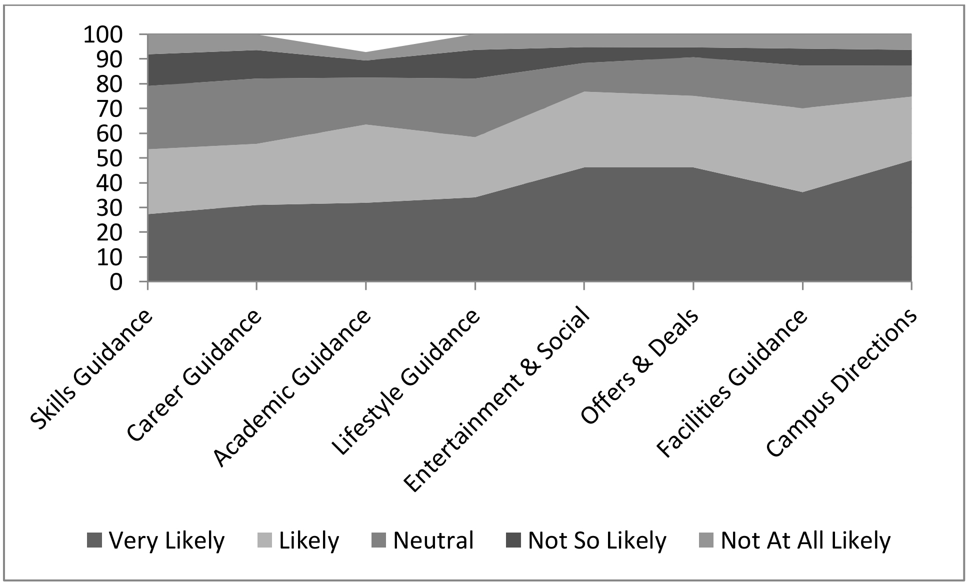


Figure 36. First Questionnaire - Smartphone Application Feature Use Likeliness

The interpretation of these likeliness results, coupled with the high monthly usage percentage of 45.6% and the positive importance ranking, leads to a confirmation of the sub-hypothesis by this thesis that mapping and directions are useful information to deliver in a pervasive computing context.

5.1.1.4. University Information Access

The second research objective of this thesis as described in section 1.7 was to investigate the current landscape of smartphone usage in accessing information in a university environment, by means of deductive quantitative experiments. Both student questionnaires include questions in relation to how university information is accessed, in an attempt to gather empirical data and complete the second research objective. The first questionnaire showed that social networks are the most frequently accessed source of university information used daily (several times per day and once per day) by the respondents (53.7%). At a monthly level however (several times per day, once per day, several times per week and monthly), 92.5% of respondents used the university website as the predominant source of university information, as shown in Figure 37.

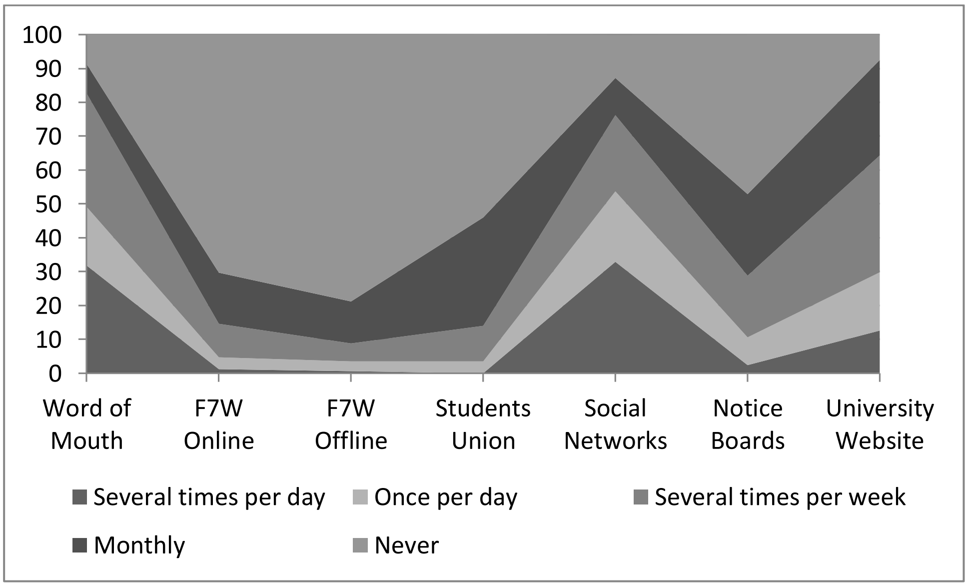


Figure 37. First Questionnaire - University Information Access

5.2. Android Application & Mobile Website

As described in chapters 3 and 4, the second deductive experiment of this thesis involved the development and deployment of an Android application and mobile website for the First Seven Weeks programme over the period of the first semester of the 2012/13 academic year (September to December). Part of this experiment involved the collection of usage and analytics data that act as observational results of the second experiment. Further evaluation results gathered from the second questionnaire relating to the deployment are presented in section 5.3.1.

5.2.1. Results & Findings

The results presented in this section comprise of multiple data sources and collection methods including usage analytics data gathered using Google Analytics, the Google Play Developer's Control Panel[48] and New Relic[49], as well as usage data gathered from the custom logging feature included in the Android application as described in section 4.3.2.4.

5.2.1.1. Android Application Google Analytics Data

During the deployment of the Android application from September to December 2012 a total of 185 users, with 164 devices, downloaded the application as shown in Figure 38. By these 185 users, the application was used 1,323 times for an average of 3 minutes and 14 seconds. 86.2% of the users used the application more than once.

---

[48] Google Play Developer's Control Panel: https://play.google.com/apps/publish

[49] New Relic: http://www.newrelic.com

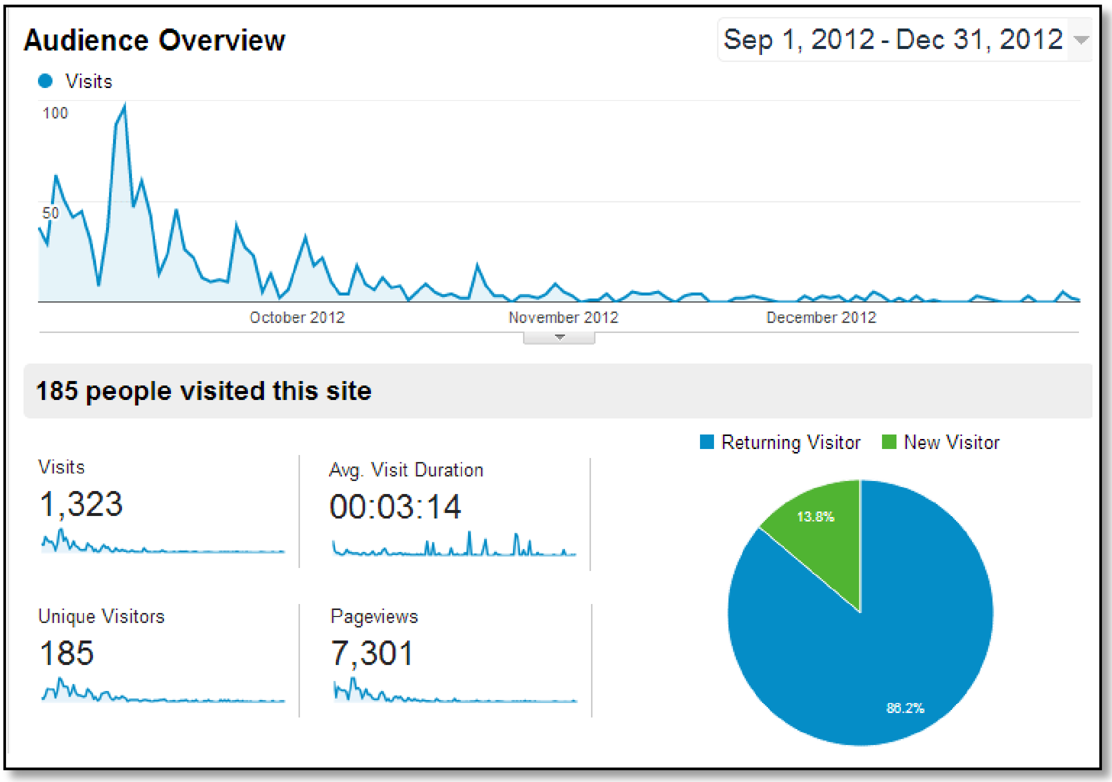


Figure 38. Android Application - Analytics Overview

The most used screen of the application was the home screen (26.25%), followed by the Building List screen (20%) and the Mapping Interface (18.8%). Of all the First Seven Weeks Weekly Theme Information pages, the first week was the most accessed screen within the application at 49.8% followed by the second week at 15%.

5.2.1.2. Mobile Website Google Analytics Data

During the deployment of the mobile website 656 users visited the site 948 times, leading to a total of 1,882 page views on the site, as shown in Figure 39. Each user spent on average 1 minute and 32 seconds on the site, accessing on average 1.99 pages per visit. 66.9% of visitors used the site more than once.

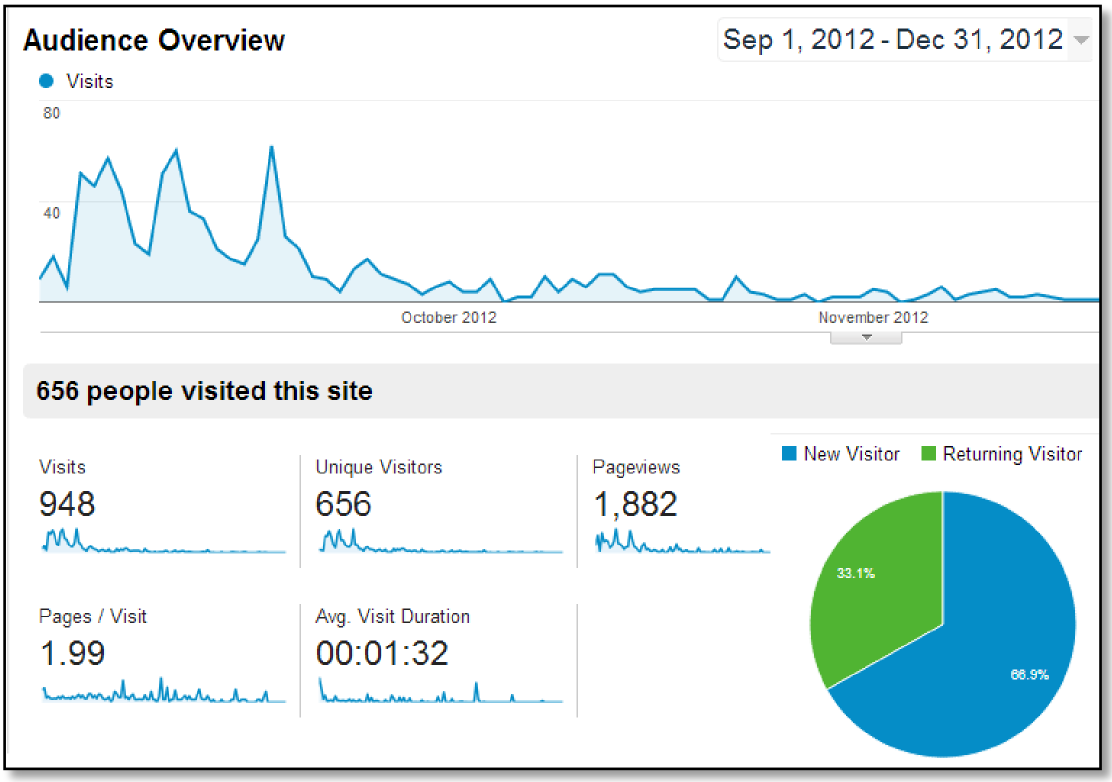


Figure 39. Mobile Website - Analytics Overview

Of all the pages accessed on the mobile website, the homepage[50] was accessed most often (39.7%) followed by the QR Code landing page[51] (17.2%), the First Seven Weeks Programme Information Page[52] (6.5%) and the Week 1 Page[53] (5.7%). The QR Code landing page was accessed 294 times, therefore the QR code posters placed in the undergraduate buildings in the University of Limerick, as described in section 4.3.2.3, were scanned by users outside of the First Seven Weeks Android application 294 times. The event analytics also show that from within the mapping interface, the

---

[50] First 7 Weeks mobile Website Homepage: http://first7weeks.ul.ie

[51] QR Code Landing Page: http://first7weeks.ul.ie/download.html

[52] First 7 Weeks Programme Information Page: http://first7weeks.ul.ie/menulist

[53] First 7 Weeks Week 1 Information Page: http://first7weeks.ul.ie/menulist/page/17

QR codes were scanned 47 times by users wanting to pinpoint their position on the indoor floormaps.

5.2.1.3. New Relic Website Analytics Data

New Relic provides application and server monitoring as a SaaS (Software As A Service) tool. By installing a plugin on the Amazon AWS cloud hosting server, analytics data regarding the health and performance of the Drupal CMS and the web server itself is sent to New Relic. An online control panel and weekly report emails are provided to the user allowing a number of data indicators to be monitored, such as number of views, average page load time and percentage error rate. This shows the monitoring data provided by New Relic for the first two weeks of the deployment of the Drupal CMS as part of the second deductive experiment.

During the first week, an average page load time of 10.4 seconds was reported. Action was taken to reduce this time by using the New Relic software to determine what parts of the application were causing the delay. Using the application profiling tools within the New Relic control panel, it was determined that the Views module within Drupal was not utilising a caching mechanism. Once this was activated, the average page load time reduced by four seconds. It is believed the remainder of the delay is caused in some part by the DNS based domain redirect from the UL servers to the amazon AWS servers. As a result of the profiling and visibility of activity on the Amazon AWS server provided by New Relic, the performance of the Drupal CMS, and thus the mobile website and the delivery of content to the Android application were improved.

5.2.1.4. Android Application Usage Data

As described in section 4.3.2.4, a system to log user interaction data was developed and included in the deployment of the Android application to allow more detailed analytics of usage of the mixed granularity indoor wayfinding mapping interface to be gathered from users that opted-in to participate in the research experiment. The logging anonymously captures the unique device id and details of each mapping interface interaction event to allow a behavioural analysis to be conducted on the collected data. The schema and format of this logging data is presented in Appendix F. During the time horizon of the deductive experiment, 5,756 unique usage events are recorded by 108 consenting participant devices out of a total of 164 devices, yielding a sample rate of 65.85%.

5.2.1.4.1. Study Discipline

On the research disclaimer screen of the Android application, as presented in Appendix A.2, each participant has the option of selecting the study discipline in which they are studying. Within the dataset of consenting participants, study discipline was selected 145 times with Engineering being the most prevalent at 20.7%, followed by Science at 19.3%, as shown in Figure 40.

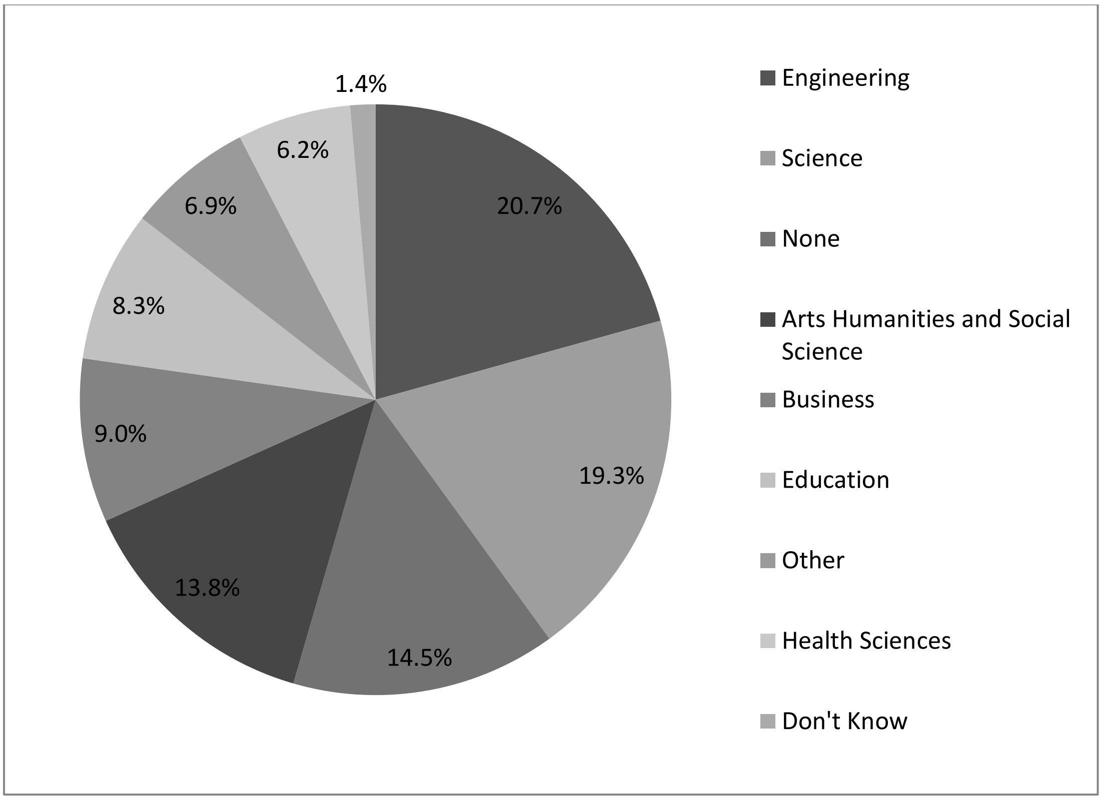


Figure 40. Application Logging - Study Discipline

5.2.1.4.2. Mapping Interface Usage

The logging data further details the use of the mapping interface and expands on the data collected from Google Analytics presented in the previous section. From the logging data, the Main Building had the highest number of logged node click, room selection, direction modal use and QR code scan events at 46.1%, followed by the CSIS building at 11.8% as shown in Figure 41.

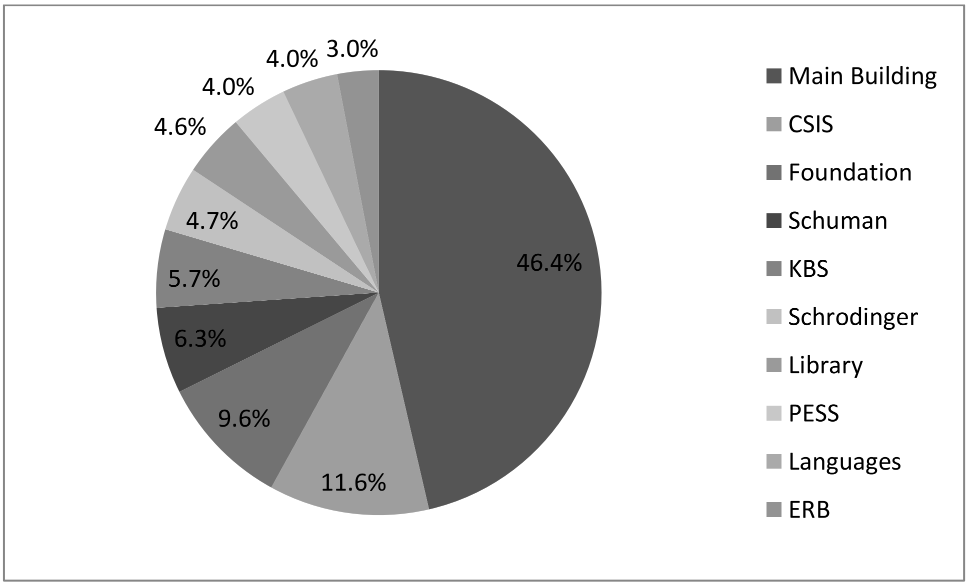


Figure 41. Application Logging - Mapping Interface Usage

In terms of the breakdown of these logged events, 45% were node clicks where the user taps a node on the mapping interface floormap to view information about that node such as what rooms are located there and around the node, as shown in Figure 42. Room selections accounted for 38% of the events, where the user selects to view the coarsely granular location of a room (i.e. the node or path where the room is located, not the precise location) using the room filter list (Figure 15) of node directional explorer modal popup (Figure 13). The use of the direction modal popup whereby users explored the points of interest at or around a particular node accounted for 38% of the events. The remainder of these logged events were QR code scans (6%) whereby the user scanned a QR code placed within the building (described in section 3.5.3.7) to pinpoint their location on the floormap.

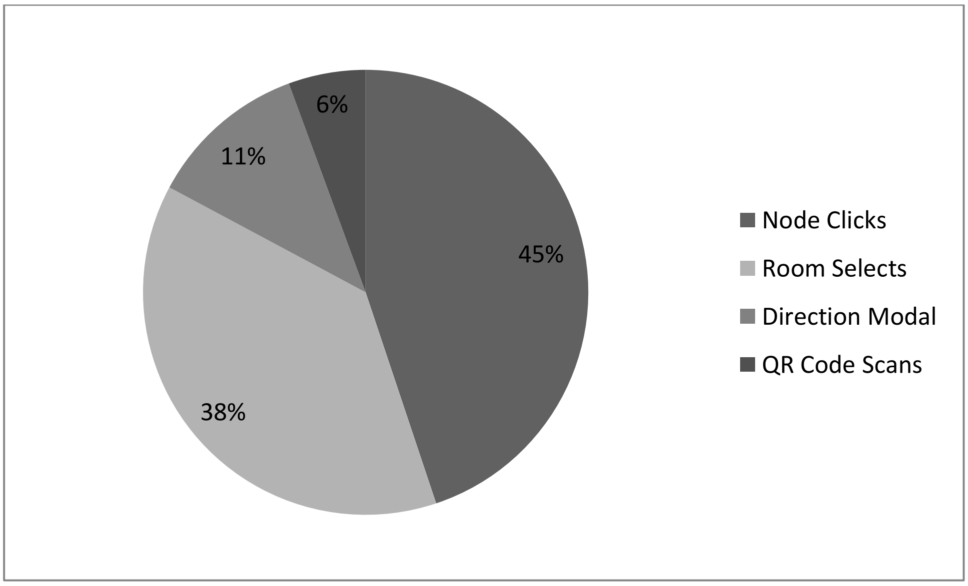


Figure 42. Application Logging - Logged Event Types

5.2.1.4.3. Room Selection

Using the room list modal popup as presented in Figure 15, the user can select a room to be highlighted in each floormap of the mapping interface. The analysis of the mapping interface usage during the timeline of the experiment shows that lecture-halls were the most selected using the mapping interface (28%), followed by entrances, exits and laboratories (16%), as shown in Figure 43.

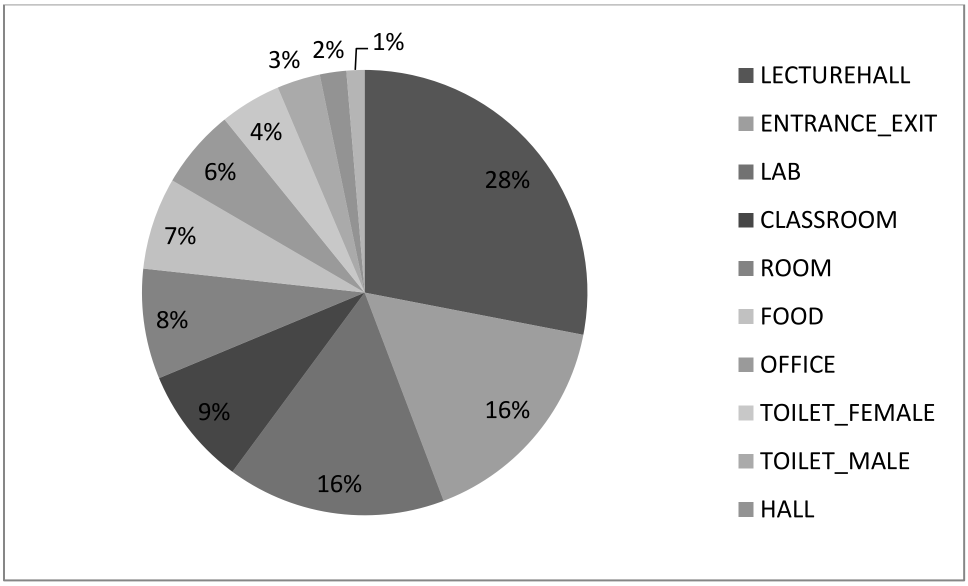


Figure 43. Application Logging - Room Type Selections

The top ten rooms selected through the experiment are shown in Figure 44, with the Main Building Main entrance being the most selected room (39%). This high percentage was most likely caused by the fact that this node was the first shown on the first floormap displayed when the Main Building was selected. The second most selected room (11%) is CSG-027, a tutorial room in the CSIS building outside which the QR code for the CSIS was placed, which may also contribute to the 11% of selections. The third most selected room was Subway, the fast food outlet in the Main Building. It is safe to assume that the 2.5% selection for this room was not influenced by any QR code placement or default floormap display and was in fact a popular location to which users of the mixed granularity indoor wayfinding solution navigate. The remainder of the top ten selected rooms consist of a Starbucks, the Charles Parsons lecture hall, a laboratory, a tutorial room, an exit and toilets.

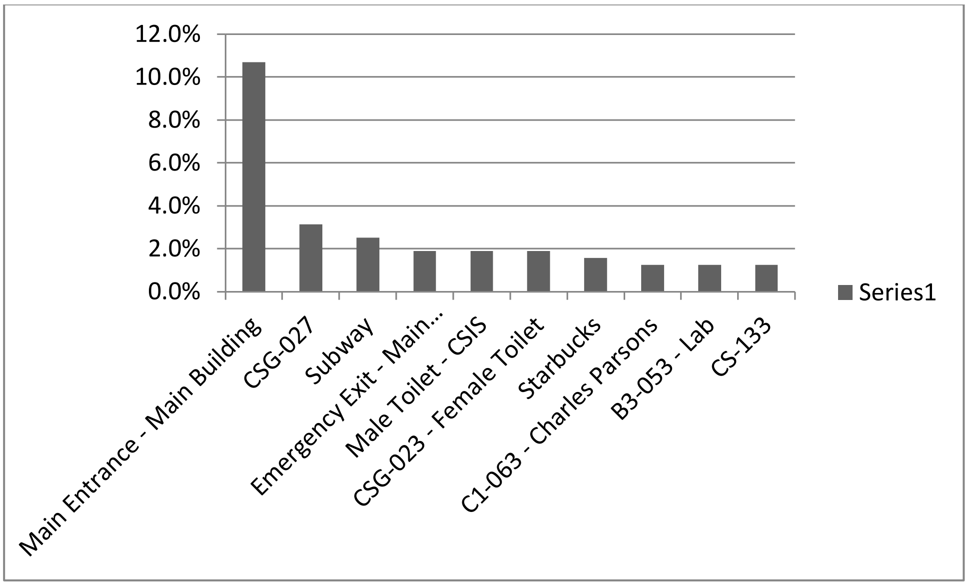


Figure 44. Application Logging - Top 10 Rooms Selected

The results show that 132 room selections occurred using the room filter list within the mapping interface (Figure 15) whereas only 16 room selections occurred using the directional modal popup (Figure 13) where users explore the rooms located around floormap nodes, as shown in Figure 45.

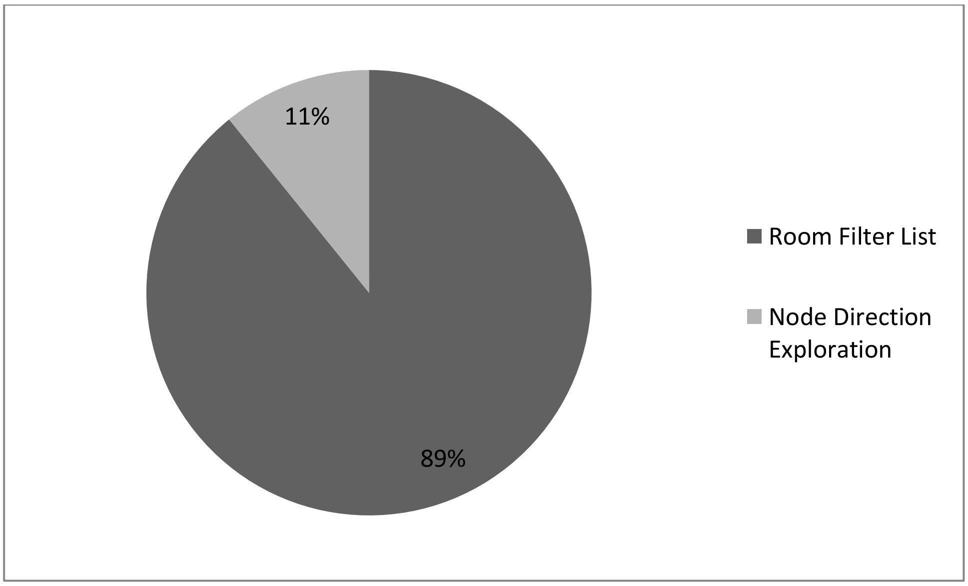


Figure 45. Application Logging - Room Selection Methods

5.2.1.4.4. Wayfinding Routes

During the experiment, 105 routes were plotted using the mixed granularity mapping interface. 42.8% of these routes were plotted in the Main Building. The most popular type of route plotted within the Main Building was to and from a toilet. The results show 9 routes plotted from a male toilet to the main entrance and 11 routes plotted to a male toilet, 10 of which are from the main entrance. Throughout the experiment across the ten undergraduate buildings, the most prevalent starting position of the routes plotted was a lecture hall (44%), followed by an entrance/exit (25%) and a classroom (10%), as shown in Figure 46.

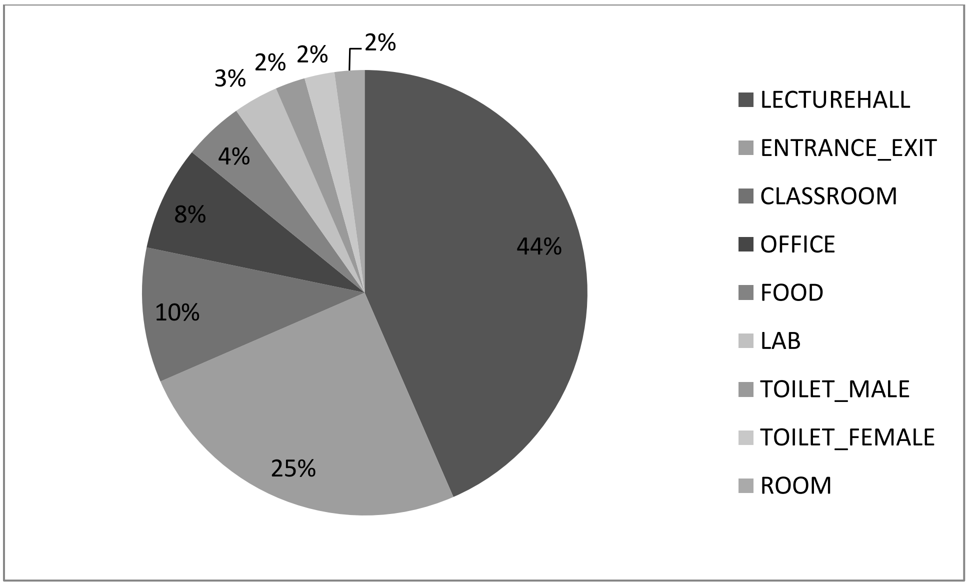


Figure 46. Application Logging - Route Starting Points

The most prevalent destination points among the routes plotted using the mapping interface were labs (19%), followed by classrooms (18%) and lecture halls (18%), as shown in Figure 47.

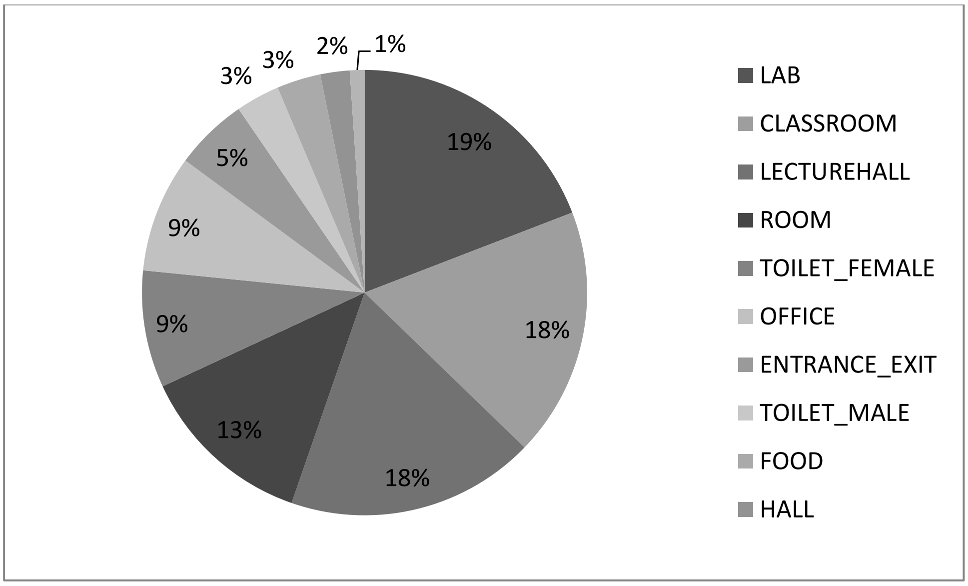


Figure 47. Application Logging - Route Destination Points

5.2.1.4.5. Usage Durations & Patterns

The cumulative duration of each user interaction with the mapping interface is analysed from the application logging data to show an average duration of use of 14 minutes and 56 seconds, with the highest cumulative duration of usage at 5 hours, 23 minutes and 54 seconds. Analysing the usage data on a per day basis shows that the majority of users (51.9%) accessed the mapping interface on just one day, as shown in Figure 48, followed by 21.3% using the mapping interface across two days and 11.1% across three days.

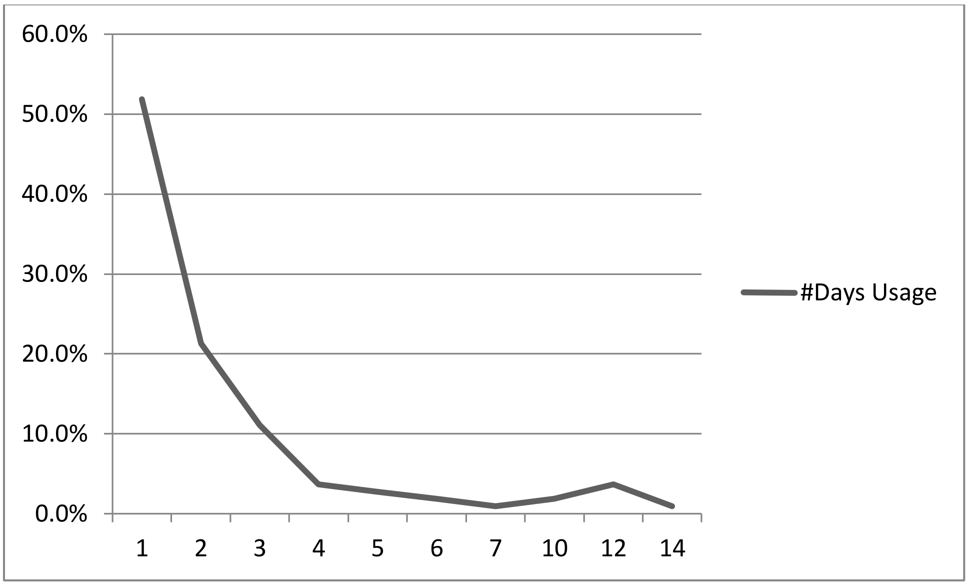


Figure 48. Application Logging - Days Usage

The analysis of usage patterns per hour by all users show a sharp increase in the use of the mapping interface starting at 08:00 each morning and peaking at 13:00. This timeframe coincides with the start of the college day and the start of the traditional lunchtime window, as shown in Figure 49.

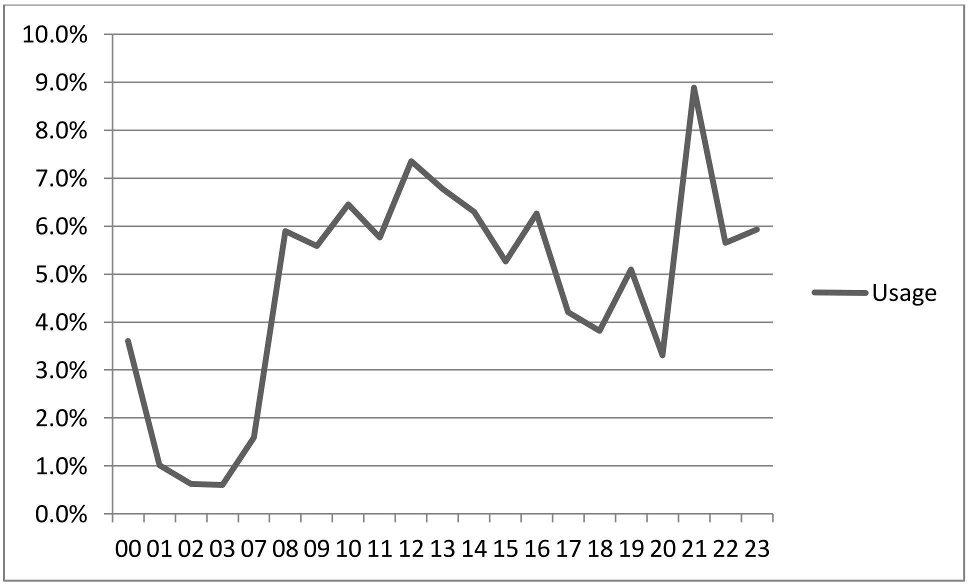


Figure 49. Application Logging - Usage Patterns

An unexpected finding within the usage pattern results was that usage peaks again from 20:00 onwards through to past midnight, which appears to indicate that users access the mapping interface to obtain wayfinding information for their lectures the next day. Although the mapping interface was primarily designed for use within the indoor environment during the process of wayfinding, these usage patterns demonstrate that it was effective in delivering a virtual model of the environment within which remote wayfinding can be conducted, similar to the plan based navigation described in the virtual versus real world environment navigation experiments (Darken, et al., 2002). Further segmentation of this hourly usage data provides a more detailed view of the scenarios within which the mapping interface was accessed. Partitioning the data into hourly quarters shows that between 30 minutes and 45 minutes past the hour was when the mapping interface was most often used (28.7%), followed by 25.4% usage in the first 15 minutes of the hour, 23.4% usage in the last 15 minutes of the hour and 22.5% usage in the second 15 minutes of the hour. Taking into account that the standard duration of timetabled lectures and tutorials in the University of Limerick was 50 minutes, starting on the hour, this infers that users accessed the mapping interface most frequently for wayfinding information, 28.7% of the time, as or just before a class or lecture was finished (30 to 45 minutes past the hour) to find out where their next classroom or lecture hall was located.

5.2.1.4.6. QR Code Scanning

The logging data also shows that the QR codes were scanned using the Android application a total of 47 times, with the majority of the QR codes in the main building being scanned (55%) as shown in Figure 47. Unfortunately, due to a development oversight the tracking of the exact QR code was omitted from the initial deployment. As a result, the locations of the 47 QR codes that were scanned were unknown.

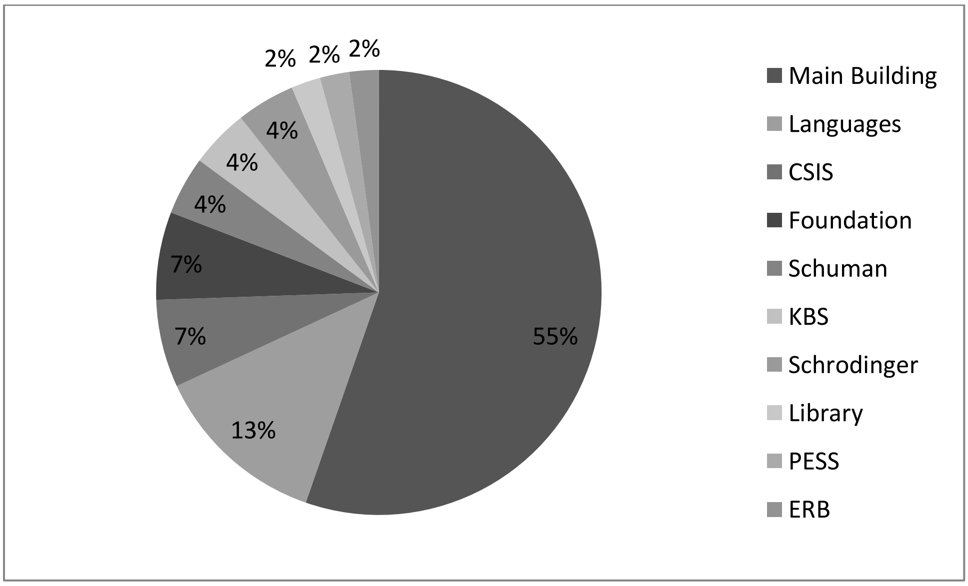


Figure 50. Application Logging - QR Code Scanning

5.2.1.5. Mobile Devices

The Google Play Developer control panel provides information about the types of Android devices that install the First Seven Weeks Android application. From this, a leader board of most prevalent Android devices among the Android application users can be ascertained, as presented in Figure 51.

Android Device Name	Percentage
Samsung Galaxy S2	30.2
Sony Ericsson Experia Arc	10.4
HTC Wildfire S	6.4
Samsung Galaxy Ace	5.6
Samsung Galaxy Mini	4.9
Samsung Galaxy Nexus	4.3

Figure 51. Android Application Device Install Base

A list of device types for users that access the mobile website was also available using the Google Analytics data. This list is presented in Figure 52 and shows the dominance of the Apple iPhone among device ownership. A point to note in relation to both lists of devices, the popularity of the Sony Ericsson Experia Arc was most likely due to that device being available in a promotional offer among network operators during the time horizon of the deductive experiments.

Mobile Device Name	Percentage
Apple iPhone	27.9
Sony Ericsson Experia Arc	10.4
Samsung Galaxy S2	6.4
Samsung Galaxy Mini	5.6
Samsung Galaxy Ace	4.9
Apple iPod Touch	2.4

Figure 52. Mobile Website Device Usage Base

5.3. The Second Questionnaire

As described in section 3.4.2, the third deductive experiment conducted in this thesis was a second questionnaire among first year students in the University of Limerick during February 2013. The questionnaire was circulated via email and is included in Appendix A.6.

5.3.1. Results & Comparative Findings

The total number of questionnaire respondents aged over 18 years of age is 204. The relevant data collected was restricted to participants over the age of 18 in accordance with the research ethics guidelines as described in section 3.8. 196 of the respondents were first year students, which was the eligible cohort this experiment aimed to analyse. With the total number of registered first year students for the 2012/13 academic year at 2,682, the questionnaire yields a response rate of 7.3%, which was treated by this thesis as a representative sample of the first year undergraduate population of the University of Limerick. This sample rate also matches the sample rate of the first questionnaire, allowing for a valid comparison of the results of both experiments. The results were collected in the format of a CSV export from an online Google Forms[54] questionnaire. Any categorical descriptive data within the result set were recoded as numerical values for analysis using the IBM SPSS statistical analysis software package. An example of this was the recoding of all of the Likert scale question results, which were stored using their text description in the Survey Monkey export data set and were recoded as 1-5 numerical values to represent the five point Likert scale. IBM SPSS was then used to determine frequency statistics for all questions and correlation statistics for a subset of question pairs. Full results to each question are presented in Appendix A.3.

5.3.1.1. Respondent Study Discipline

Among this population, as shown in Figure 53, 29.1% studied in the discipline of Arts, Humanities and Social Sciences, 26% in Science, 18.4% in Engineering, 9.7% in Business 9.2% in Health Science and 7.7% in Education.

[54] Google Forms: http://www.google.com/google-d-s/createforms.html

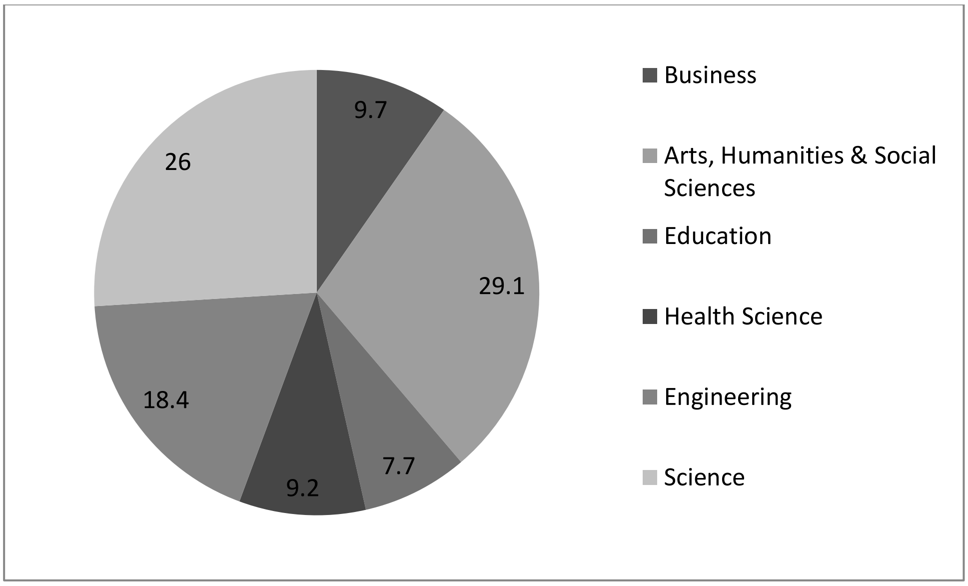


Figure 53. Second Questionnaire - Respondent Study Discipline

In comparison to the study discipline results of the first questionnaire, the largest increase in questionnaire participation among respondents was in those studying Arts, Humanities and Social Sciences, which increased by 8.4%, as shown in Figure 54. The largest decrease in participation was among those studying Business, which decreased by 4.8%.

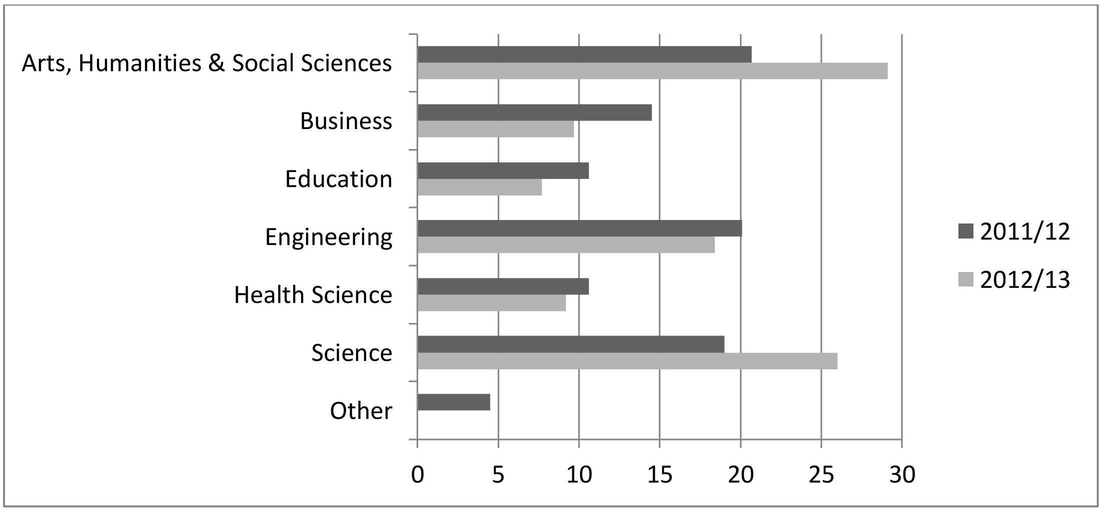


Figure 54. Both Questionnaires - Study Discipline

The relationship between smartphone ownership and study discipline was analysed using a significance test. The null hypothesis that these is no relationship between study discipline and smartphone ownership was accepted (and maintained from the first questionnaire) based on the results of a Chi-Square test and Cramer's V association measure which resulted in a chi-square value of 2.14 with 5 degrees of freedom where p was 0.833, showing no significance. The Cramer's V value of 0.104 showed a positive association however at the insignificant 0.833 level. These results are presented in Figure 55.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
UseSmartphone * StudyDiscipline	196	100.0%	0	0.0%	196	100.0%

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.104			.833
	Cramer's V	.104			.833
Interval by Interval	Pearson's R	-.014	.068	-.195	.846[c]
Ordinal by Ordinal	Spearman Correlation	-.012	.067	-.165	.869[c]
N of Valid Cases		196			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.114[a]	5	.833
Likelihood Ratio	2.198	5	.821
Linear-by-Linear Association	.038	1	.845
N of Valid Cases	196		

a. 3 cells (25.0%) have expected count less than 5. The minimum expected count is 2.83.

Figure 55. Second Questionnaire - Study Discipline Vs Smartphone Ownership Significance Test

5.3.1.2. Smartphone Penetration & Landscape

The results of the second questionnaire showed that 81.1% of first year students owned a smartphone. This percentage indicates a 5.3% increase in smartphone ownership over a two academic year period, as shown in Figure 56, confirming the sub-hypothesis presented as part of this third deductive experiment in section 1.8.4, that smartphone ownership among the first year student population was increasing. Of these smartphone owners, 37.7% of respondents acquired their smartphone in the last six months.

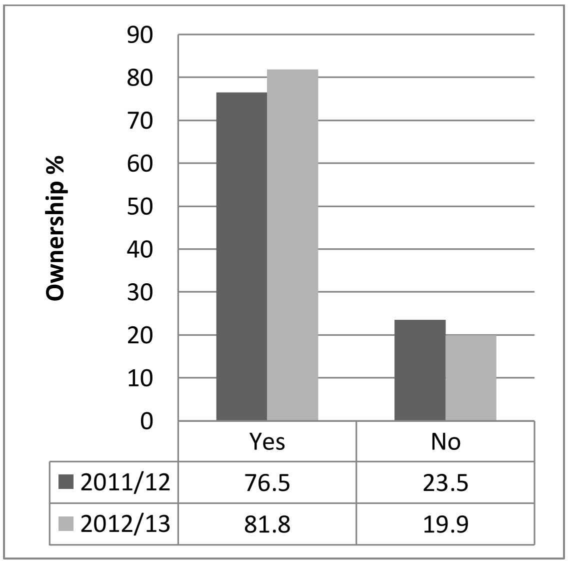


Figure 56. Both Questionnaires - Smartphone Ownership Comparison

The Google Android operating system was shown to be the most prevalent smartphone platform with 58.5% of the respondents owning Android phones, an increase of 12.5%, as shown in Figure 57. Second to Android, 26.4% of respondents' smartphones were Apple iPhones, a decrease of 6.4%.

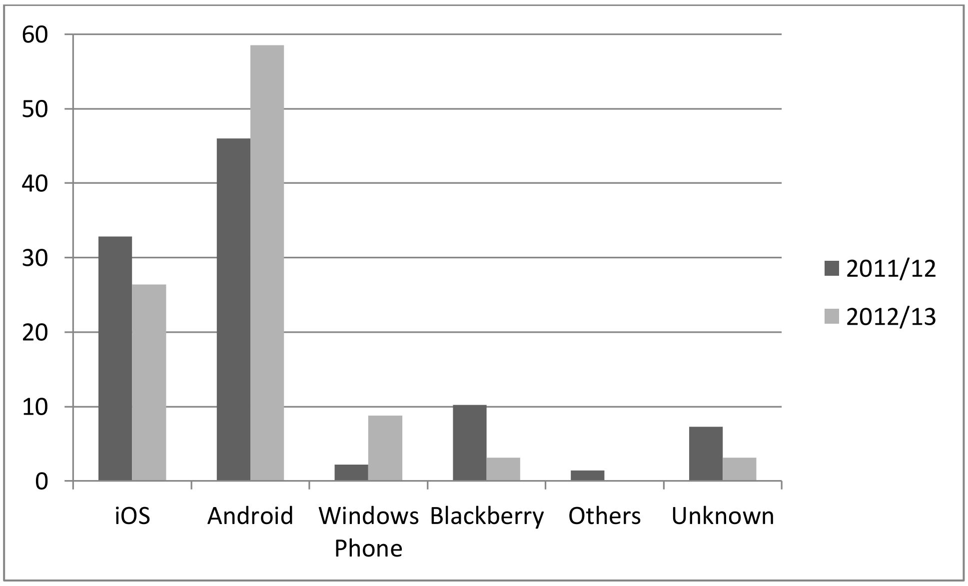


Figure 57. Both Questionnaires - Operating System Comparison

Other headline results regarding the smartphone landscape among first year students showed that among Android users, v4.1 Jelly Bean was the most prevalent operating system (15.1%). A gradual upgrade trend can be seen in Figure 58, with respondents moving from Froyo (v2.2) and Gingerbread (v2.3) to Ice Cream Sandwich (v4.0) and Jelly Bean (v4.1+) over the two academic years.

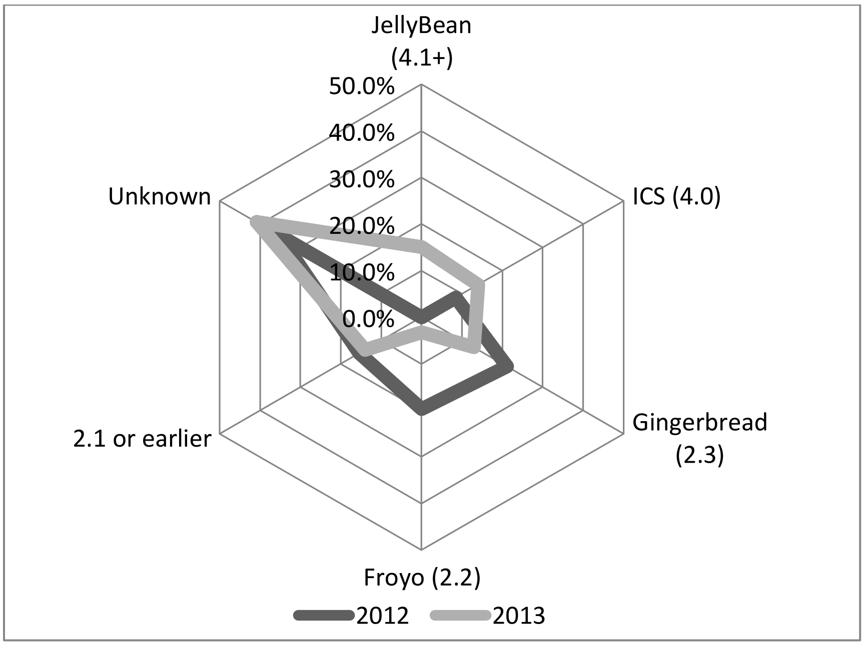


Figure 58. Both Questionnaires - Android OS Comparison

Among iPhone users, iOS v6.x was the most prevalent operating system (66.7%), with a major shift from iOS v5.x over the two academic years, shown in Figure 59. The results also showed that majority of respondents (71.1%) were engaged on pre-pay contracts with their mobile phone network operator.

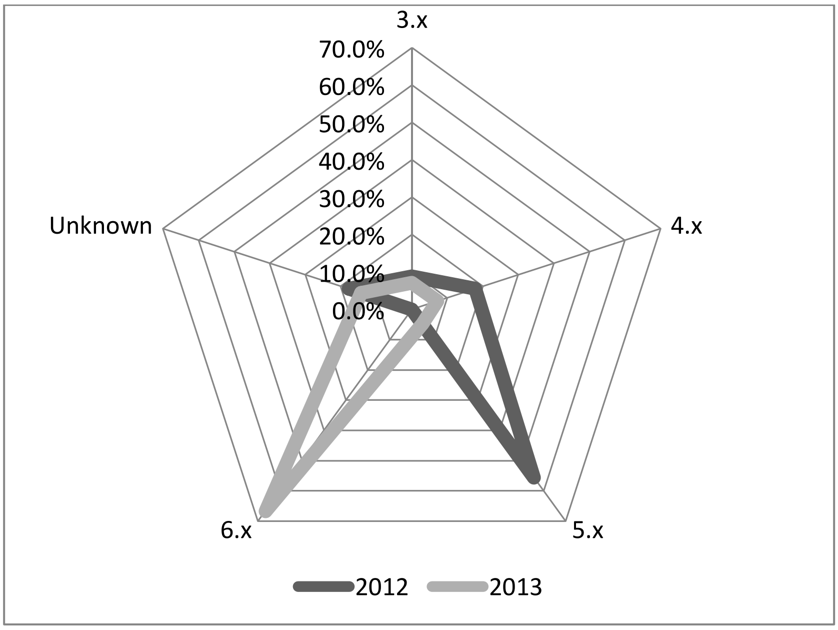


Figure 59. Both Questionnaires - iOS Comparison

Only 18.9% of respondents intended on getting a new smartphone within the next year while 54.1% did not intend on getting a smartphone within a year. When the 18.9% were asked why they intended on getting a smartphone, web browsing, using apps and social networking were the main reasons given, as shown in Figure 60.

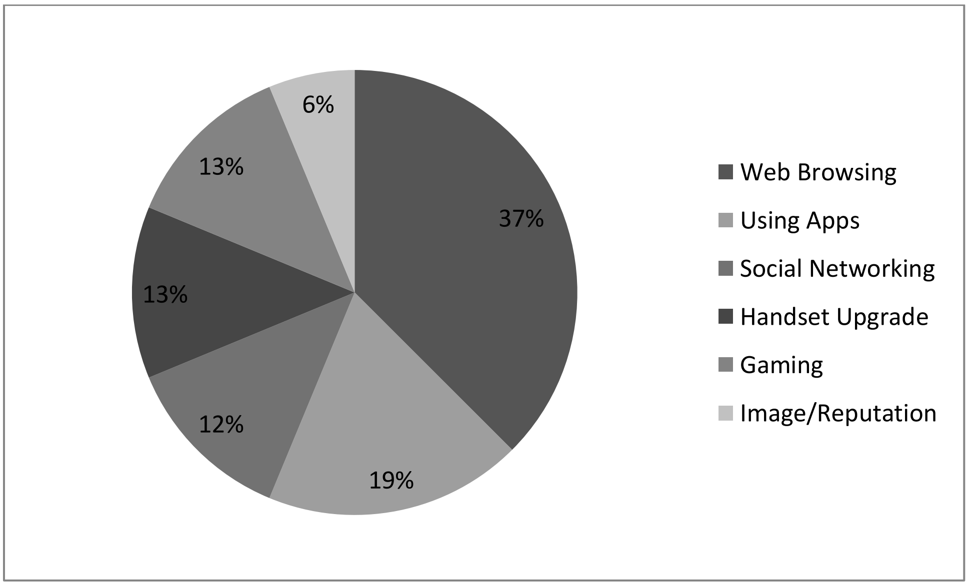


Figure 60. Second Questionnaire - Reasons to get a smartphone

When the 54.1% of respondents who stated they have no intention of getting a smartphone in the next year were asked why, no need, cost and unwanted extra features were the main reasons given, as shown in Figure 61.

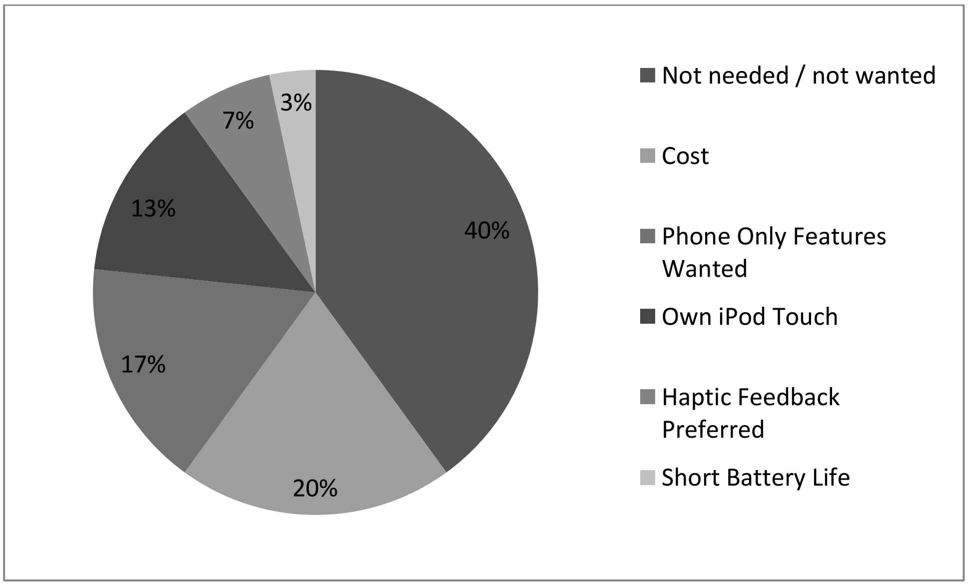


Figure 61. Second Questionnaire - Reasons not to get a smartphone

5.3.1.3. Feature Importance

The results of the second questionnaire showed that Web Browsing (81.7%), Using Apps to Access Info (79.2%) and Social Networking (76.7%) were the most important smartphone features among respondents, as shown in Figure 62. These results represent a drop in importance for Web Browsing by 2.2% and an increase in importance for Apps (9.4%) and Social Networking (2.3%). Unfortunately, due to an administration oversight, the questions relating to how often each respondent uses the features of their smartphone were omitted from the second questionnaire. As a result a comparative analysis of feature usage with the results of the first questionnaire was not possible.

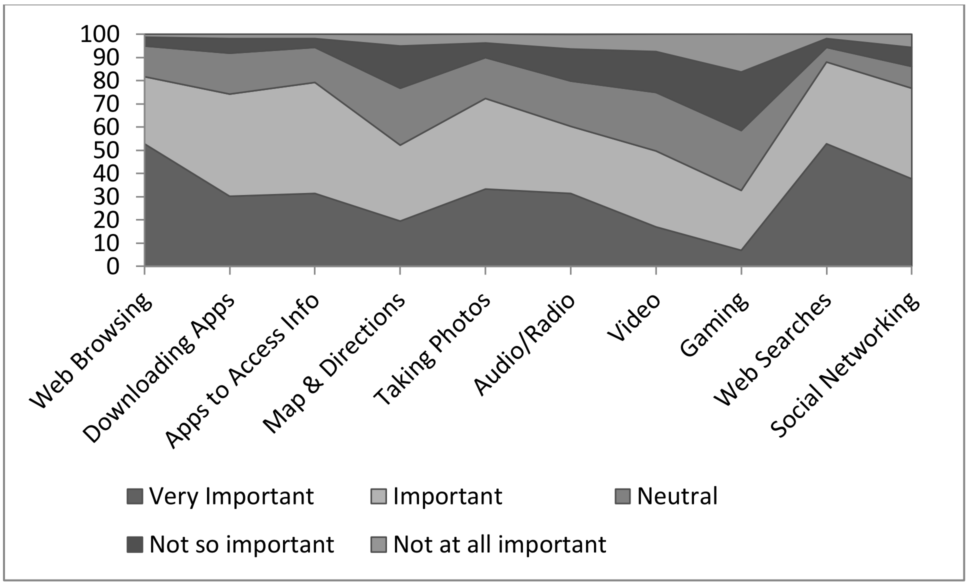


Figure 62. Second Questionnaire - Feature Importance

In comparison to the results of the first questionnaire, a large increase in importance was recorded for the features Using Apps To Access Information and Downloading Apps. A coefficient of overall sentiment was calculated for each feature across both questionnaires by deducting the sum of the negative importance ratings (Not so Important and Not At All Important) from the positive importance ratings (Very Important and Important) and is presented in Figure 63. These calculations illustrate an increase in the importance of 16.2% for Using Apps To Access Information and an increase of 10.8% in the importance of Downloading Apps. Unfortunately, due to an administration oversight, the feature usage questions included in the first questionnaire were excluded from the second questionnaire. As a result, a comparative analysis of feature usage across both sets of observational results was not possible.

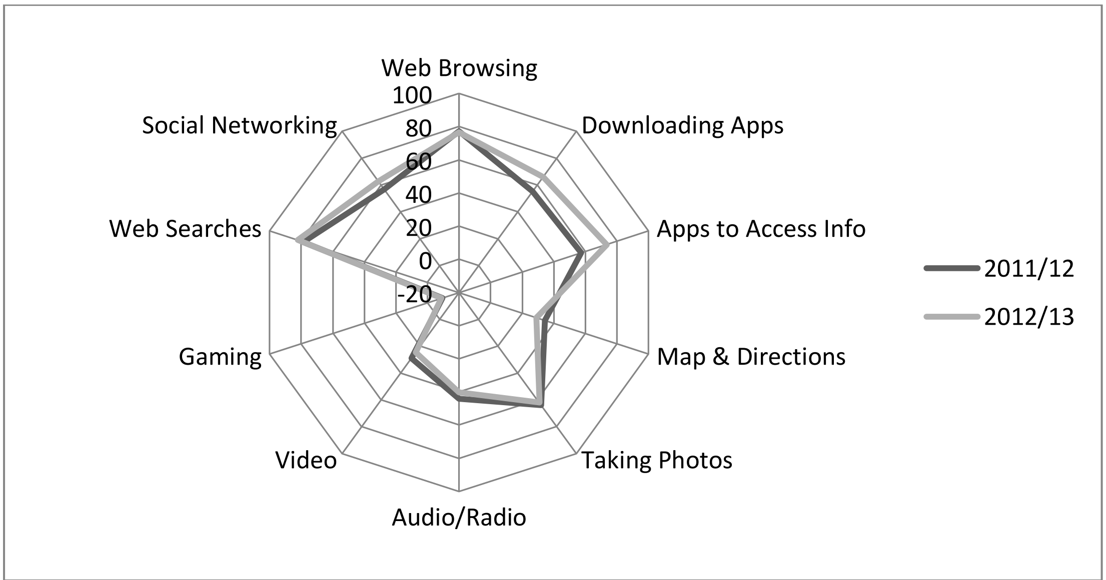


Figure 63. Both Questionnaires - Feature Importance

5.3.1.3.1. Maps & Directions Feature Importance

In the context of feature importance, the respondents that deemed the feature very important and important rose by 0.3% and those that deemed it not so important declined by 6.5%. Overall however, the importance of the feature across each positive point of the scale decreased by 0.3% over the two academic years.

5.3.1.4. University Information Access

The second questionnaire results showed that Social Networks remained the most frequently used data sources when accessing university information with daily access (several times per day and once per day) rate of 52.1%, as shown in Figure 64, which declined by 1.6% from the previous academic year. The second most frequently accessed data source was Word of Mouth at 32.1%, down 17% from the previous academic year. The second questionnaire includes the First Seven Weeks Android Application as a data source for university information access, as deployed using the second deductive experiment by this thesis. 12.2% of respondents reported using the application on a monthly basis (several times per day, once per day, several times per week and monthly).

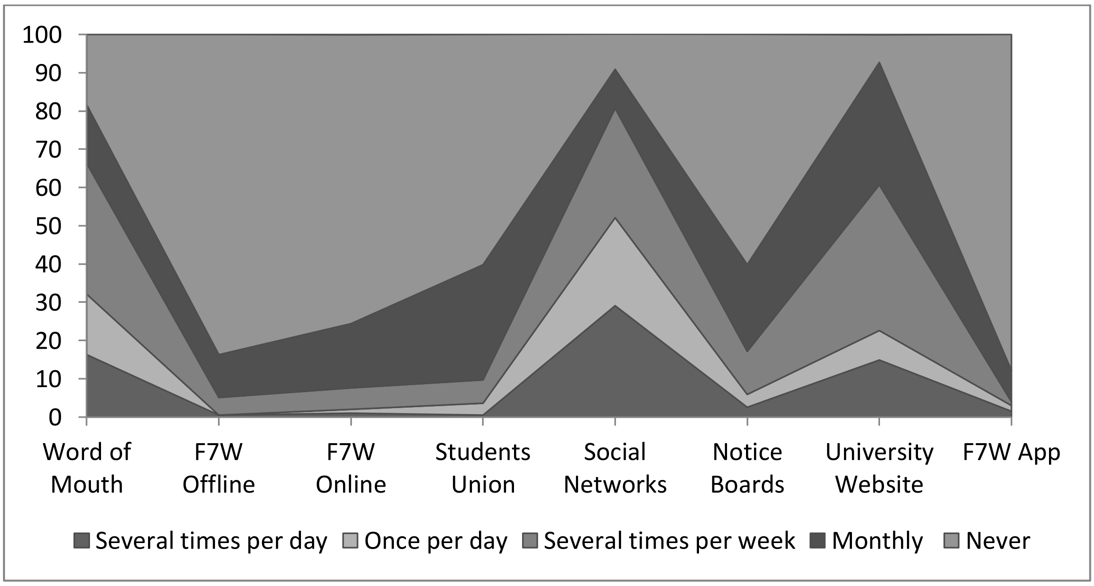


Figure 64. Second Questionnaire - University Information Access

In comparison to the results of the first questionnaire, the largest increase in data source usage was for Social Networks which increased by 3.7%, as shown in Figure 65. The largest decrease was in the use of the First Seven Weeks Offline method of information access which decreased by 13.4%. A possible reason for this sharp decline was the deployment of the Android application and mobile website by this thesis which delivers the same information to users, and showed 12.2% usage among respondents.

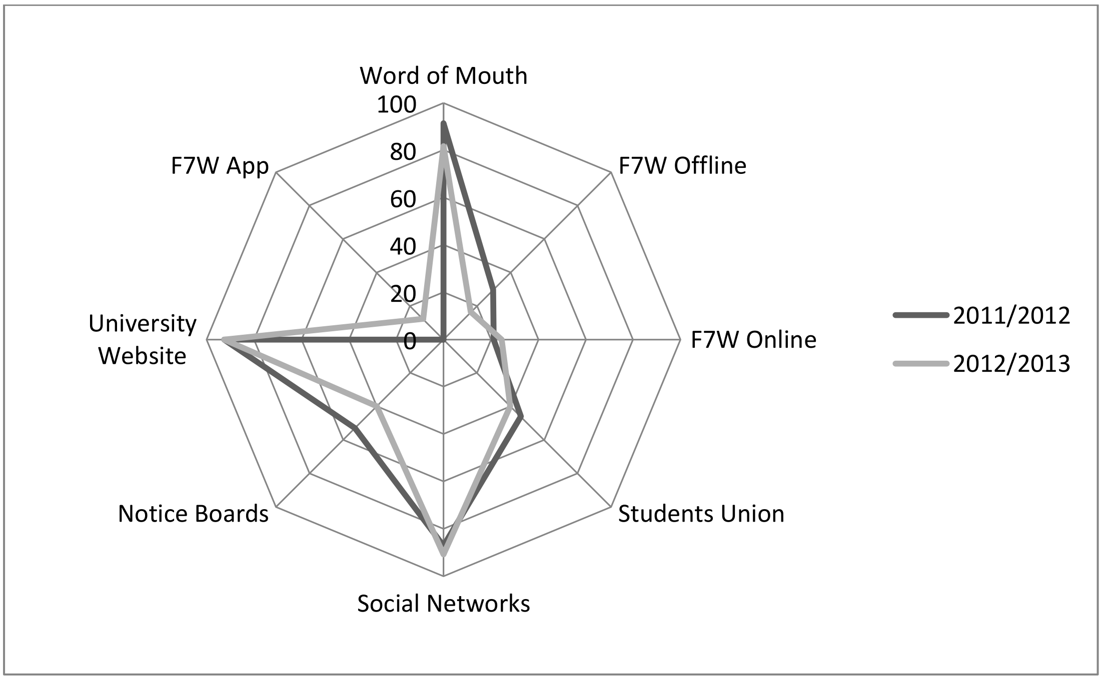


Figure 65. Both Questionnaires - University Information

5.3.1.5. First Seven Weeks Android Application and Mobile Website

The second questionnaire included a number of questions in relation to the First Seven Weeks Android application and mobile website. These questions aimed to evaluate the deployment of the second deductive experiment. 53.7% of respondents indicated that they are aware of the existence of the First Seven Weeks Android application and mobile website. Respondents were asked which features of the First Seven Weeks Android application they used and how often these features were accessed. The results showed that accessing the mixed granularity indoor wayfinding features of the Android app were used most frequently on a daily basis (once per day and several times per day). 12.3% of respondents access the indoor floormaps for the Main Building and 11.3% of respondents access the floormaps of the other buildings daily, as shown in Figure 66. On a monthly basis (once per day, several times per day, several times per week and monthly), accessing the First Seven Weeks Facebook page[55] was the most frequently used feature at 17.8%, followed by accessing the floormaps of the other undergraduate buildings at 16.9% and the access of the Main Building floormaps at 15.9%. 7.6% of respondents scanned the First Seven Weeks QR Codes not using the Android application on a monthly basis, and 6.1% scanned the QR codes using the Android application to pinpoint their position on the indoor floormaps. In terms of the information delivered by the First Seven Weeks Programme, the weekly themed information was accessed by 12.2% of respondents on a monthly basis, followed by the access of the theme documents at 11.7% and the photos and videos at 10.2%.

---

[55] First Seven Weeks Facebook Page: https://www.facebook.com/first7weeks

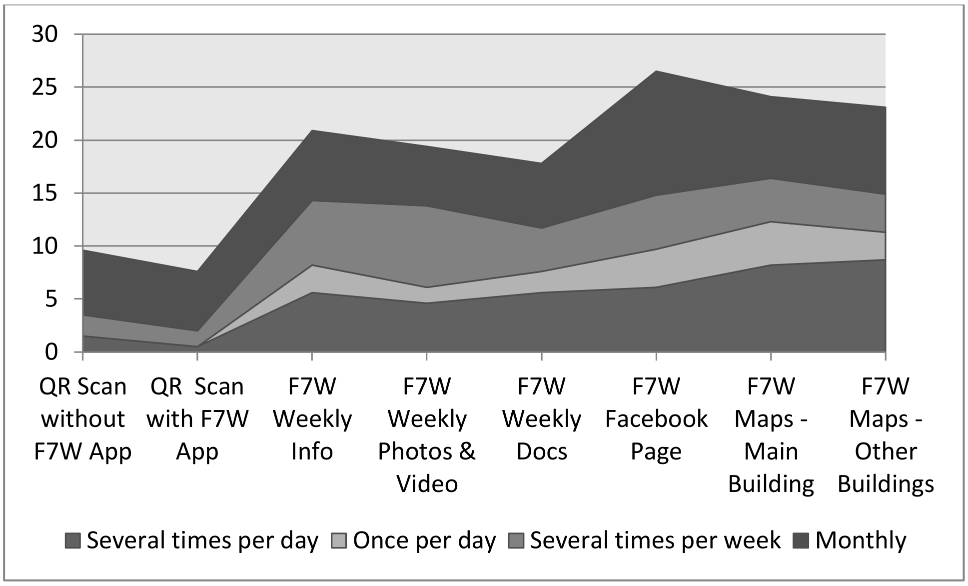


Figure 66. Second Questionnaire - First 7 Weeks Android App Feature Usage

The usefulness of the mapping interface features was also rated by respondents of the questionnaire. Of the respondents that used each feature of the smartphone application, 22.6% found the Room List feature most useful (Very useful and Useful). A close second was the ability to check a floormap while not being in a particular building, which has a positive usefulness rating of 22.4%. 20.4% of respondents state that using the mixed granularity indoor wayfinding system was useful in learning their way around the indoor environment. The application logging results presented in 5.2.1.4.5 reinforce this result, whereby most of the daily usage of the mapping interface occurred at night where users accessed the mapping interface the night before being due on campus. For each feature rating however, between 50% and 54% of respondents stated they did not use the features. Figure 67 shows the usefulness of each feature among the respondents that stated usage.

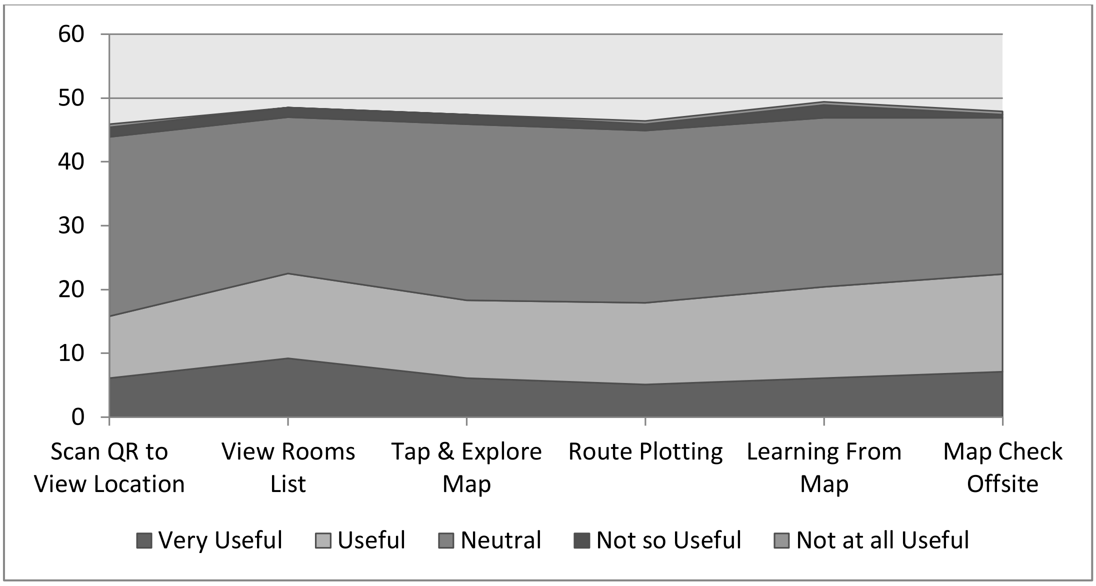


Figure 67. Second Questionnaire - Mapping Interface Feature Usefulness

Respondents were asked to rate their enjoyment of using the First Seven Weeks Android application to explore and find their way around each building. 9.7% of respondents indicated a positive enjoyment rating however 16.9% indicated a negative enjoyment rating. Respondents were asked to rate the positive effect the First Seven Weeks Android application had on their experience of starting college at UL. 12.8% indicated a positive rating however 14.2% indicated a negative rating.

5.4. Data Analysis Conclusions

The collection and analysis of the observational data gathered from the three deductive experiments presented in the previous sections of this chapter illustrate the completion of the fourth research objective of this thesis stated in section 1.7, to evaluate the mixed granularity indoor wayfinding solution through quantitative analysis of data from multiple sources. In addition, the second research objective, the investigation of the current landscape of smartphone usage in a university environment, is also addressed using the analysis of quantitative data.

5.4.1. Smartphone Usage in a University Environment

The investigation into the domain of smartphone usage in accessing information in a university environment was primarily addressed by way of the two questionnaires conducted by this thesis. Both deductive experiments include questions about how respondents access university information most frequently. The results presented in sections 5.1.1.4 and 5.3.1.4 show that social networks have replaced word of mouth as the second most frequently accessed source of university information however the university website remains the primary university data source in a university environment. In the wider environment of accessing all types of information, the results analysed by this thesis show that the pervasive computing data access scenario, specifically the use of smartphone features, has become an increasingly important channel to disseminate university information. The sub-hypothesis of the third deductive experiment, that smartphone ownership among the first year student population is increasing, was upheld and supported by the increase in smartphone ownership among respondents of 5.3%, as described in section 5.3.1.2. Among undergraduate smartphone users, the Google Android operating system was shown to be the most prevalent smartphone platform, with an increase of 12.5% in ownership. Furthermore, the importance of downloading and using smartphone applications to access information in a university environment was rated as increasingly important, as described in section 5.3.1.3.

5.4.2. Mixed Granularity Indoor Wayfinding Evaluation

The evaluation of the mixed granularity indoor wayfinding mapping interface was conducted by analysing the results of the second questionnaire in combination with the usage data collected from the Android application. The second questionnaire asked respondents to rate a number of different aspects of the mapping interface such as feature usage and experience evaluation, as described in section 5.3.1.3. The results showed that the mapping interface was the most used feature of the First Seven Weeks Android application. Accessing the floormap and room list information, both during the process of wayfinding and in preparation using remote wayfinding the night before (section 5.2.1.4.5), as well as using the mapping interface to learn their way around (i.e. aid in the creation of a mental image of the environment), were the most useful features. The usage data presented in section 5.2.1.4 show that multiple methods were used to access the wayfinding information presented by the mapping interface, such as the node directional exploration modal popup (Figure 13) and the room selection filter list (Figure 15). The route planning and QR code scanning features were also used to assist the user in the act of wayfinding, albeit not used as widely. Both of these sources of quantitative observational data uphold the sub-hypotheses of the second deductive experiment, that orientation information can be delivered and consumed effectively in a pervasive context using a smartphone device and that a mixed granularity approach to indoor wayfinding is effective in allowing users to navigate in an indoor environment. An important point to note however is that, as described in section 5.3.1.5, the enjoyment rating for using the mapping interface to explore an indoor environment, as polled by the second questionnaire, showed a negative ratio at 1.74:1 negative to positive. Respondents of the questionnaire also report a negative ratio of 1.1:1 negative to positive of the positive impact the First Seven Weeks Android application had on their experience of starting college at UL. The explanation for these negative ratings somewhat impacts on the evaluation of the mixed granularity indoor wayfinding solution, however to determine their specific impact and the reasons behind the ratings, further experiments are needed, such as qualitative interviews with respondents, which are currently outside the scope of the time horizon of this thesis.

5.5. Summary

This chapter presents the quantitative observational data collected by the three deductive experiments conducted by this thesis. The data from the first and third experiment, the two questionnaires, are described and comparatively analysed. The usage and interaction data collected from the Android application and mobile website are presented and analysed. The data from each experiment uphold the sub-hypotheses presented in section 1.8.4 and also address the second, third and fourth research objectives defined by this thesis. The observational results support the creation of a grounded theory that the mixed granularity indoor wayfinding system is successfully exemplified by this thesis. This grounded theory is described in more detail in the next chapter.

6. Conclusion

6.1. Introduction

Mystification and discovery are key components in the enjoyment and human experience of wayfinding and fundamental to its success. This thesis explores this theory, proposed by Lynch (1960), by applying it to indoor wayfinding using a mixed granularity wayfinding solution in a pervasive computing context.

6.2. Mixed Granularity Indoor Wayfinding

Many technological solutions exist that aid the process of wayfinding indoors. The majority of these are hybrid solutions that attempt to augment or replace the use of global satellite navigation system signals which when used outdoors provide accurate positional information however on their own do not provide accurate positional data in an indoor environment due to signal degradation. One of the most common technologies used as part of these hybrid solutions is pedestrian dead reckoning (PDR) which counts the number of steps taken by the user and the direction in which the user travels to determine their position indoors. These hybrid solutions deliver varying degrees of positional accuracy and oftentimes require additional fixed infrastructure to provide more accurate results. Not to be constrained by these limitations, this thesis takes an alternative approach in implementing a solution that aids in wayfinding indoors. This proposed solution does not focus on providing pin-point accurate positional data but rather concentrates on providing coarsely granular wayfinding information coupled with mechanisms to deliver finely granular information at fixed points. This mixed granularity approach allows the wayfinding information to be disseminated to and interpreted by the user during wayfinding but also maintains the need for the user to explore and discover the indoor environment. Furthermore, this approach aids the user in creating a cognitive map of their environment, slowly reducing the need of the user to require the use of the solution to aid in wayfinding. The genesis of this mixed granularity approach comes from the exploration of the wayfinding concepts presented by Lynch wherein the optimal balance of information versus exploration for the user is obtained when "*confusion must be small regions in a visible whole*" (Lynch, 1960, p. 6). This thesis extrapolates this concept into a pervasive computing landscape using a smartphone application and applies it to an indoor wayfinding scenario. This smartphone application was deployed among first year undergraduate students in the University of Limerick over a two year time period, the results of which form part of a larger research approach to exemplifying the pervasive computing approach to mixed granularity indoor wayfinding.

6.3.Research Overview

The research question of this thesis is to determine if a mixed granularity approach to indoor wayfinding in a pervasive computing context can be exemplified. To achieve this, a mixed method quantitative deductive and inductive approach is defined which employs a grounded theory strategy. This mixed method approach consists of three experiments, two deductive and one inductive combined with an inductive data analysis phase. Four research objectives also overlap these experiments as a part of the research approach. Firstly, a literature and state of the art review of existing smartphone technology approaches used to implement indoor wayfinding is conducted, presented in Chapter 2. Secondly, the current topic of smartphone usage in accessing information in a university environment is investigated within the first and third experiments. Thirdly, a mixed granularity approach to indoor wayfinding in a pervasive computing context is investigated, implemented and delivered as a smartphone application within the second experiment. Lastly, this delivery is evaluated through quantitative analysis of observation data from multiple sources. The data produced by the three experiments combined with the information produced in the execution of the four research objectives is used to define the grounded theory in answer to the research question.

6.4. Experimentation, Evaluation & Limitations

The experiments conducted and research objectives completed by this thesis allow a grounded theory to be induced in answer to the research question.

6.4.1. Indoor Wayfinding Literature

The literature review conducted and presented in Chapter 2 firstly highlights the theory that the balance of mystification and feelings of lost-ness during wayfinding is a delicate one that needs to be maintained by reassuring the user (Darken, et al., 2002), thus protecting the emotional security of the user and their ability to successfully create a cognitive map of their environment (Lynch, 1960). Secondly, the literature points to many technical solutions that aid the user in wayfinding indoors by attempting to provide positional information in as accurate a manner as possible. There exists a lack of solutions however that specifically focus on allowing the user to experience the mystification of exploration within a known framework, which is what the mixed granularity indoor wayfinding solution presented by this thesis aims to achieve.

6.4.2. Student Questionnaires

The first and third experiments conducted by this thesis were questionnaires that collect information from first year undergraduate students in the University of Limerick across a two academic year time frame. One aim of these questionnaires was to investigate the smartphone usage landscape among students, to ascertain how smartphones were currently used and how university information was accessed by students. Both questionnaires allowed for a comparative study across two years, which showed a smartphone ownership rate of 81%, which increased over the time frame of the two questionnaires. Web browsing was the most popular smartphone feature used by students and downloading and using applications to access information increased in popularity over the course of the two questionnaires. The results also showed that social networks and the university website were the most frequently accessed data sources for university information. The first questionnaire also acts as deductive information source within the research approach of this thesis. It provides information that guides the requirements and design of the smartphone application delivered in the second experiment. The Android smartphone platform was confirmed as the most popular platform among students and thus the best development platform to use, and the popularity of mapping and directions functionality within a university application was also ascertained. The second questionnaire (third experiment) also acts as an inductive source of information. The deployment of the mixed granularity indoor wayfinding solution was evaluated by this questionnaire and the results were combined with the quantitative usage data collected in fulfilment of the fourth research objective.

6.4.3. First Seven Weeks Android Application and Mobile Website

The second experiment conducted by this thesis was in fulfilment of the third and fourth research objectives and involves the design, development, deployment and evaluation of the mixed granularity indoor wayfinding solution using an Android smartphone application. The deployment of this application also formed part of a collaborative project with the Centre for Teaching and Learning (CTL) in the University of Limerick. The collaboration involved the creation of a smartphone application for the First Seven Weeks Programme which is an orientation programme conducted by the CTL. The project involved delivering the orientation information to students using a mobile website and the smartphone application, which in turn allowed the smartphone application to act as a pervasive computing platform to deploy the mixed granularity indoor wayfinding solution. Within the mapping interface of the application, the mixed granularity approach was achieved by displaying indoor floorplans of each undergraduate building to the user which provide coarsely granular wayfinding information such as the framework of the building and network of navigation paths and nodes within. Finely granular information such as room locations and points of interest are presented at a node and path level as opposed to pinpointing the exact location, forcing the user to explore "the last mile" of the wayfinding process themselves, thus maintaining the mystification of exploration. For example, the corridor where a classroom is located is displayed but the user needs to explore the corridor to find the exact location of the classroom within the corridor. Furthermore, a bridge between the coarse and fine granularity of the wayfinding information was provided using QR codes placed at the main entrances/exits and stairwells of buildings, allowing the user to re-orientate them-selves during wayfinding by scanning the QR code using the application which then displays the finely granular location on the floormap, thus reassuring the user and maintaining the comfort of not becoming lost.

6.4.4. Evaluation

The deployment of the experiment was conducted over an academic semester that lasted four months, during which time usage data from the mapping interface of the Android application was collected from users who opted in to be part of the research project. This observational data, coupled with the evaluation data from the second questionnaire confirm that the mixed granularity indoor wayfinding solution was successfully used by users during wayfinding within the undergraduate buildings of the University of Limerick. Event logging functionality within the application tracked the usage of various features within the mapping interface, the most used of which were node clicks and room selects. When a room was selected, the coarsely granular location of the room was displayed to the user. 89% of users utilised the room select filter list when selecting a room whereas 11% utilised the node select modal popup to view and explore the rooms in the vicinity of the node and the most popular rooms selected were lecture halls. The routing feature was also used, primarily to display directions from lecture halls and entrances to laboratories and classrooms. This appears to confirm a landmark route survey (LRS) structure of the cognitive map of the user whereby the lecture halls are the main landmarks that are learnt first, followed by routes to less frequented tutorial classrooms and laboratories. The usage duration patterns of the application show a decline after 3 days of usage (Figure 48) indicating that the need to use the application as an aid to wayfinding diminishes over time, possibly because the user has created a cognitive map of sufficient fidelity at that point. Further analysis of the usage patterns of the application show, unexpectedly, that the majority of interactions with the mapping interface took place outside of teaching hours and primarily at night (Figure 49). This indicates that the application was used by students the night before to reference the location of their lectures and tutorials the next morning, allowing them to build a survey based cognitive map of the day ahead. The interaction data also showed that the scanning of the QR codes only accounted for 6% of the interactions. During the second experiment, users were asked to rate their enjoyment level at using the mapping interface to find their way around, which resulted in a negative to positive response ratio of 1.74:1. This may suggest that the feeling of confusion due to the unknown environment is greater than the feeling of mystification experienced during wayfinding with the aid of the mapping interface. It may also suggest that because users may be so familiar with pin-point accurate positional information provided by other wayfinding technology that the effort involved in exploring areas and building a cognitive map is no longer enjoyable for the most part for users. Users of the mapping interface did however indicate a positive reaction to the question relating to using the application to learn their way around an environment (8.16:1 positive to negative response ratio). As indicated by the usage information and results of the second questionnaire, users were aware of the smartphone application and actively used the mixed granularity indoor wayfinding solution to view the locations of rooms, explore nodes on the floormaps, plot routing directions and scan QR codes. These most popular features of the mapping interface can be categorised or coded into two categories; a survey knowledge category and a route knowledge category. The ability to select and view the location of rooms on the floormaps and to tap nodes and explore the location of POIs around a node form the survey knowledge category, whereby a user accesses the information by way of reference to build a cognitive map. The plotting and display of route directions and the scanning of QR codes to display current location form the route knowledge category, whereby users active in the process of wayfinding interact directly with the wayfinding information in-situ to aid in the process of wayfinding. On examination of these categories and their respective features, all display information in a mixed granularity fashion, which maintains the core aim of the approach to aid in formation of a cognitive map by maintaining the mystification aspect of exploration and discovery. Furthermore, all features aid in the user becoming familiar with an indoor environment. The usage data and questionnaire results captured and categorising as described demonstrated effective usage of the solution to aid in wayfinding indoors. The implemented solution and all of its features employed a mixed granularity approach to the interaction with, and presentation of, the wayfinding information. This approach combined with the observational data collected infers the grounded theory that this thesis answers the research question posed, by successfully exemplifying the implementation of a pervasive computing approach to mixed granularity indoor wayfinding.

6.4.5. Limitations

A number of limitations existed that reduced the scope of the thesis in certain areas. One such limitation was the time horizon of this thesis. A number of prioritisation decisions were necessary in order to ensure the core experiments and research objectives were completed which resulted in some planned inclusions to be excluded. Examples of these exclusions are the planned augmented reality functionality of the mapping interface and the planned second android application to allow the creation of the floormaps primarily using footstep detection and PDR. In both cases however, workarounds such as the manual overlay of the PDF floormaps and the re-scoping of the wayfinding features to not include outdoor navigation allowed for the research to continue unabated. Another exclusion from this thesis as a result of time constraints was a fourth experiment involving a set of qualitative interviews with users of the mapping interface of the application. The intention was to perform passive and active cognitive walk-through interviews with a sample set of user to observe the usage of the mapping interface while users perform tasks using the mapping interface while articulating their actions allowed. Following this and post walk through interview would capture more information from the user and all results were to be coded and analysed in an attempt to further evaluate the effectiveness of the mapping interface. Approval from the research ethics board was granted for these interviews however the time constraints of the thesis delivery mean that this experiment was unable to be conducted. The intended interview test plan is presented in Appendix H. Another limitation encounter which is outside the control of this thesis is the approval process for iPhone applications. The strictness of this process led to the decision not to build the smartphone application for iOS as well as Android due to the unpredictability of the application being approved including the relevant ethics disclaimer form and custom interaction logging feature.

6.5. Future Work & Research

Addressing the evaluation limitation described in the previous section is the first proposed area of future research. Detailed evaluation methods of a deployed solution such as a cognitive walkthrough, video review and interview are described (Skorupka, 2009). Using these techniques to gather additional quantitative and qualitative evaluation data would go towards improving the mixed granularity indoor wayfinding solution even further. Further additional features added to the solution can also be considered future work. Examples of such features are textual route directions, which would give the user a set of text based directions when plotting a route between two points. The evaluation of route directions as described by Lovelace could be taken into account in the design of this feature to include the most effective route directions for both familiar and unfamiliar environments (Lovelace, et al., 1999). Another feature that can be considered as future work is the addition of alternate routing algorithms such as a reliable path algorithm (Haque, et al., 2007) which generates paths which may not be the shortest but are the paths of the least complexity, thus increasing the ease at which the user can build a cognitive map using the wayfinding information. Aside from the addition of features to the existing solution, at a macro level a number of other implementation and deployment scenarios for the solution exist. The deployment of the mixed granularity indoor wayfinding solution is exemplified by this thesis in an indoor university environment however when treating the solution as a scalable and adaptable framework other scenarios exist within which the solution can be the deployed, especially given the pervasive nature of the approach. Deployment within retail environments such as shopping malls is conceivable whereby the solution guides the user to the location of a store but the user must explore within the store, coupled with QR code scanning to identify certain products, discounts or special offers within the store. Another, perhaps more conducive deployment environment is within tourism based scenarios such as museums. The mixed granularity indoor wayfinding solution would enable the user to explore exhibits while being directed to the location of different collections. This delivery of mixed granularity wayfinding information may also be more relevant because it is generally not a time sensitive scenario where users are not under time pressure and thus have more time to exploring the indoor environment.

6.6. Summary

This chapter presents a summary of the indoor wayfinding problem area identified by the literature review performed within this thesis. The concepts of mystification during wayfinding are presented as the core concept upon which the exemplification of a pervasive computing approach to mixed granularity indoor wayfinding is based. The research approach used to exemplify this solution is presented with details regarding the experiments conducted and research objectives achieved. The results of these experiments and research objectives are evaluated and a grounded theory is defined in answer to the research question posed by this thesis. Finally, limitations encountered in this thesis are presented along with proposed directions for future work and research in the area.

References

Abowd, G. D. I. L. &. M. H., 2005. Guest Editors' Introduction: The Smart Phone–A First Platform for Pervasive Computing.. *IEEE Pervasive Computing*, Volume 4(2).

Ahn, J. & Han, R., 2011. *Rescueme: An indoor mobile augmented-reality evacuation system by personalized pedometry..* s.l., IEEE Services Computing Conference (APSCC).

Akula, M. D. S. et al., 2011. Integration of infrastructure based positioning systems and inertial navigation for ubiquitous context-aware engineering applications.. *Advanced Engineering Informatics*, Issue 25.

Allen, G. L., 1999. Spatial abilities, cognitive maps, and wayfinding.. In: *Wayfinding behavior: Cognitive mapping and other spatial processes.* s.l.:JHU Press, pp. 46-80.

Ben Shneiderman, C. P., 2010. *Designing The User Interface.* s.l.:Pearson.

Casas, R. et al., 2007. Hidden Issues in Deploying an Indoor Location System.. 6(2), p. 62–69.

Chang, C., 2009. *Spatial Design and Reassurance for Unfamiliar Users when Wayfinding in Buildings.* Sheffield: University of Sheffield, School of Architecture.

Chen, W. & al., e., 2011. Comparison of EMG-based and accelerometer-based speed estimation methods in pedestrian dead reckoning.. 64(02), pp. 265-280.

Cho, D.-K. & al, e., 2010. *AutoGait: A mobile platform that accurately estimates the distance walked..* s.l., IEEE international conference onPervasive computing and communications (PerCom).

Clinch, S., 2013. Smartphones and pervasive public displays.. 12(1), pp. 92-95.

Cook, D. J. &. D. S. K., 2012. Pervasive computing at scale: Transforming the state of the art.. *Pervasive and Mobile Computing*, 8(1)(10.1016/j.pmcj.2011.10.004), p. 22–35.

Darken, P., R. & Peterson, B., 2002. Spatial orientation, wayfinding, and representation.. In: *Handbook of virtual environments.* s.l.:s.n., pp. 493-518.

Dijkstra, E. W., 1959. A note on two problems in connexion with graphs.. 1(1), pp. 269-271.

Dillemuth, J., 2005. Map design evaluation for mobile display.. 32(4), pp. 285-301.

Dix, A., Finlay, J., Abode, G. & Beale, R., 2004. *Human Computer Interaction.* s.l.:s.n.

Filonenko, Viacheslav & Carswell, J., 2009. *Hybrid Indoor Positioning and Directional Querying on a Ubiquitous Mobile Device.* Dublin, s.n.

Frankenstein, J. & al., e., 2012. The language of landmarks: the role of background knowledge in indoor wayfinding.. 13(1), pp. 165-170.

Fuchs, C., Aschenbruck, N., Martini, P. & Wieneke, M., 2011. Indoor tracking for mission critical scenarios: A survey.. 7(1), pp. 1-15.

Glaser, B. G. & Strauss, A. L., 1967. *The discovery of grounded theory: Strategies for qualitative research..* Chicago: Aldine.

Goetz, M. & Zipf, A., 2011. Formal definition of a user-adaptive and length-optimal routing graph for complex indoor environments.. 14(2), pp. 119-128.

Goetz, M. & Zipf, A., 2011. Formal definition of a user-adaptive and length-optimal routing graph for complex indoor environments.. 14(3), pp. 119-128.

GPSWorld, 2011. CSR, Navizon Debut Indoor Location and Navigation Systems. *GPS World*, Issue 12, p. 27.

Gusenbauer, D., Isert, C. & Krösche, J., 2010. Self-contained indoor positioning on off-the-shelf mobile devices. Issue doi:10.1109/IPIN.2010.5646681.

Haque, S., Kulik, L. & Klippel., A., 2007. Algorithms for reliable navigation and wayfinding.. In: *Spatial Cognition V Reasoning, Action, Interaction.* s.l.:Springer Berlin Heidelberg, pp. 308-326.

Hile, H. & Borriello, G., 2007. Information overlay for camera phones in indoor environments.. In: *Location-and Context-Awareness.* s.l.:Springer Berlin Heidelberg, pp. 68-84.

Ho, C., Bro, M. & Knauff, M., 2007. Up the down staircase : Wayfinding strategies in multi-level buildings. 26(4), p. 284–299.

Hochmair, H. H., 2008. PDA-assisted indoor-navigation with imprecise positioning: Results of a desktop usability study.. In: *Map-based Mobile Services.* s.l.:Springer Berlin Heidelberg, pp. 228-247.

Jacob, R. & al, e., 2009. Campus guidance system for international conferences based on openstreetmap.. In: *Web and Wireless Geographical Information Systems.* s.l.:Springer Berlin Heidelberg, pp. 187-198.

Jul, S. & Furnas, G., 1997. *Navigation in electronic worlds: a CHI 97 workshop..* s.l., SIGCHI bulletin 29, pp. 44-49.

Khalifa, S., 2013. *Converting context to indoor position using built-in smartphone sensors..* s.l., IEE, p. 423–424.

Kim, J. & Jun, H., 2008. Vision-based location positioning using augmented reality for indoor navigation.. 54(3), pp. 954-962.

Kloch, K., Lukowicz, P. & Fischer, C., 2011. *Collaborative PDR Localisation with Mobile Phones.*. San Francisco, IEEE, pp. 37 - 40.

Koulouriotis, D., Amanatiadis, A. & Gasteratos, A., 2011. An intelligent multi-sensor system for first responder indoor navigation.. *Measurement Science and Technology*, Issue 22(11).

Kuipers, B., Tecuci, D. G. & Stankiewicz., B. J., 2003. The Skeleton In The Cognitive Map A Computational and Empirical Exploration.. 35(1), pp. 81-106.

Li, H. & Giudice, N. A., 2012. *Details-on-demand Mobile Visual Interface for Facilitating Indoor Wayfinding..* Columbus, International Conference on Geographic Information Science .

Likert, R., 1932. A Technique for the Measurement of Attitudes. *Archives of Psychology*.

Lovelace, K., Hegarty, M. & Montello, D., 1999. Elements of good route directions in familiar and unfamiliar environments.. In: *Spatial information theory. Cognitive and computational foundations of geographic information science.* s.l.:Springer Berlin Heidelberg, p. 751–751.

Low, W., Nagarajan, R. & Sazali., Y., 2009. *Simultaneous localization and map building–a guided tour..* Penang, International Conference on Man-Machine Systems.

Lyardet, F., Szeto, D. W. & Aitenbichler, E., 2008. Context-aware indoor navigation.. In: *Ambient Intelligence.* s.l.:Springer Berlin Heidelberg, pp. 290-307.

Lynch, K., 1960. *The Image of the City.* s.l.:MIT Press.

Mandel, L. H., 2011. Lost in the labyrinth: Wayfinding behavior in a public library—predictable? Maybe not.. 48(1).

Montello, D. R. & al., e., 2004. Spatial memory of real environments, virtual environments, and maps.. In: *Human spatial memory: Remembering where.* s.l.:s.n., pp. 251-285.

Mulloni, A. & al., e., 2009. Indoor positioning and navigation with camera phones.. 8(2), pp. 22-31.

Osborn, W. & Hinze, A. (., 2013. TIP-tree: A spatial index for traversing locations in context-aware mobile access to digital libraries.. 12(2).

Paterson, L. & Low, B., 2011. Student attitudes towards mobile library services for smartphones. 29(3), pp. 412-423.

Pombinho, P., Afonso, A. P. & Carmo, M. B., 2010. *Indoor Positioning Using a Mobile Phone with an Integrated Accelerometer and Digital Compass.* s.l., s.n., p. 443–446.

Roach, R., 2010. Digital remix: institutions consider latest mobile computing gadgets as campuswide instructional and communication tools.. *Diverse Issues in Higher Education*.

Robson, C., 2002. *Real world research..* Oxford: Blackwell.

Saunders, M., Lewis, P. & Thornhilll, A., 2009. *Research methods for business students.* s.l.:Pearson.

Serra, A., Carboni, D. & Marotto, V., 2010. *Indoor pedestrian navigation system using a modern smartphone..* s.l., ACM Human computer interaction with mobile devices and services.

Shahrom, M., 2013. *Relative and cardinal directions for privacy-aware personal navigation services: A comparison towards navigation efficiency..* s.l., IEEE Intelligent Sensors, Sensor Networks and Information Processing.

Shin, H., Chon, Y. & Cha., H., 2012. Unsupervised construction of an indoor floor plan using a smartphone. 42(6), pp. 889-898.

Shin, S. H., Lee, M. S., Park, C. G. & Hong, H. S., 2010. *Pedestrian dead reckoning system with phone location awareness algorithm.* Indian Wells, IEEE/ION , p. 97–101.

Shin, S. H. et al., 2007. *Adaptive step length estimation algorithm using low-cost MEMS inertial sensors..* San Diego, Sensors Applications Symposium, p. 1–5.

Skorupka, A., 2009. *Comparing human wayfinding behavior in real and virtual environment..* Stockholm, Proceedings of the 7th International Space Syntax Symposium..

Smith, P. A. & al, e., 2011. *Tracking Progress on Path for Indoor Navigation..* Aachen: RWTH Aachen University.

Tinto, V., 1988. Stages of Student Departure: Reflections on the Longitudinal Character of Student Leaving.. Issue 59(4).

Tolman, E. C., 1948. Cognitive maps in rats and men.. Issue 55.4.

Uwe Hansmann, L. M. M. S. N. T. S., 2001. *Pervasive Computing Handbook.* s.l.:Springer.

Wang, H. & al, e., 2007. Enhancing the map usage for indoor location-aware systems.. In: *Human-Computer Interaction. Interaction Platforms and Techniques.* s.l.:Springer Berlin Heidelberg, pp. 151-160.

Weiser, M., 1991. The computer for the twenty-first century. *ScientificAmerican*, 256(3), p. 94–104.

Zhang, H. & Zhao, Y., 2011. The performance comparison and analysis of extended Kalman filters for GPS/DR navigation.. Issue 122(9), p. 777–781.

Bibliography

Abascal, J., Lazkano, E., & Sierra, B. (2005). Behavior-Based Indoor Navigation. *Intelligence*, 263–285.

Abowd, G. D., Iftode, L., & Mitchell, H. (2005). Guest Editors' Introduction: The Smart Phone–A First Platform for Pervasive Computing. *IEEE Pervasive Computing*, *4*(2), 18–19.

Ahn, J., & Han, R. (2011). RescueMe: An Indoor Mobile Augmented-Reality Evacuation System by Personalized Pedometry. *2011 IEEE Asia-Pacific Services Computing Conference*, 70–77. doi:10.1109/APSCC.2011.26

Akula, M., Dong, S., Kamat, V. R., Ojeda, L., Borrell, A., & Borenstein, J. (2011). Integration of infrastructure based positioning systems and inertial navigation for ubiquitous context-aware engineering applications. *Advanced Engineering Informatics*, *25*(4), 640–655. doi:10.1016/j.aei.2011.07.006

Allen, G. L. (1999). Spatial abilities, cognitive maps, and wayfinding. *Wayfinding behavior: Cognitive mapping and other spatial processes*, 46–80.

Allen, Gary L. (1999). Cognitive Abilities in the Service of Wayfinding : A Functional Approach, *51*(February 1998), 554–561.

Alzantot, M. (2012). UPTIME : Ubiquitous Pedestrian Tracking using Mobile Phones. *Integration The Vlsi Journal*.

Anagnostopoulos, C., Tsetsos, V., Kikiras, P., & al, et. (2005). OntoNav: A Semantic Indoor Navigation System.

Asif, M., & Krogstie, J. (2011). Mobile student information system. *Campus-Wide Information Systems*, *28*(1), 5–15. doi:10.1108/10650741111097269

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications*, *21*(6), 34–47. doi:10.1109/38.963459

Ballagas, R., Borchers, J., Rohs, M., & Sheridan, J. G. (2006). The smart phone: a ubiquitous input device. *IEEE Pervasive Computing*, *5*(1), 70–77. doi:10.1109/MPRV.2006.18

Bornemann, E. (2012). Best QR Code Innovations. *Information Today*, *29*(2), 10.

Bucher, L., Röser, F., Nejasmic, J., & Hamburger, K. (2014). Belief revision and way-finding. *Cognitive Processing*, *15*(1), 99–106. doi:10.1007/s10339-013-0577-x

Bylemans, I., Weyn, M., & Klepal, M. (2009). Mobile Phone-Based Displacement Estimation for Opportunistic Localisation Systems. *2009 Third International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies*, 113–118. doi:10.1109/UBICOMM.2009.23

Carboni, D., & Tecnologico, P. (2010). Indoor Pedestrian Navigation System Using a Modern Smartphone, 397–398.

Casas, R., Cuartielles, D., Marco, A., Gracia, H. J., & Falco, J. L. (2007). Hidden Issues in Deploying an Indoor Location System. *IEEE Pervasive Computing*, *6*(2), 62–69. doi:10.1109/MPRV.2007.33

Chang, C.-L. (2009). *Spatial design and reassurance for unfamiliar users when wayfinding in buildings*.

Chen, W., Zhang, X., Chen, Y. W., Wang, J. Y., Fu, Z. Q., Chen, R. Z., & Chen, X. A. (2011). Comparison of EMG-based and Accelerometer-based Speed Estimation Methods in Pedestrian Dead Reckoning. *JOURNAL OF NAVIGATION*, *64*(2), 265–280. doi:10.1017/S0373463310000391

Cho, D., Mun, M., Lee, U., Kaiser, W. J., & Gerla, M. (2009). AutoGait : A Mobile Platform that Accurately Estimates the Distance Walked. *Electrical Engineering*.

Chung, K.-Y., Yoo, J., & Kim, K. J. (2013). Recent trends on mobile computing and future networks. *Personal and Ubiquitous Computing*, 2–4. doi:10.1007/s00779-013-0682-y

Clinch, S. (2013). Smartphones Smartphones and Pervasive, 92–95.

Collin, J., Mezentsev, O., & Engineering, G. (2003). I NDOOR P OSITIONING S YSTEM U SING A CCELEROMETRY. *Mechanical Engineering*, 1–7.

Constandache, I. (2010). Towards Mobile Phone Localization without, (1).

Cook, D. J., & Das, S. K. (2012a). Pervasive computing at scale: Transforming the state of the art. *Pervasive and Mobile Computing*, *8*(1), 22–35. doi:10.1016/j.pmcj.2011.10.004

CSR, Navizon Debut Indoor Location and Navigation Systems. (2011, December). Questex Media Group.

Dae-Ki Cho, Min Mun, Uichin Lee, Kaiser, W. J., & Gerla, M. (2010). AutoGait: A mobile platform that accurately estimates the distance walked (pp. 116–124). IEEE. doi:10.1109/PERCOM.2010.5466984

Darken, R. P., & Peterson, B. (2002). Spatial orientation, wayfinding, and representation. *Handbook of virtual environments*, 493–518.

Dix, A., Finlay, J., Abode, G., Beale, R. (2004). Human Computer Interaction, 3/e, Prentice Hall.

Duckham, M., Kulik, L., & Worboys, M. (2003). Imprecise Navigation.

Filonenko, V., & Carswell, J. (2009). Hybrid Indoor Positioning and Directional Querying on a Ubiquitous Mobile Device — Use Licence —.

Frese, U. (2006). Treemap: An O (log n) algorithm for indoor simultaneous localization and mapping. *Autonomous Robots*, *21*(2), 103–122. doi:10.1007/s10514-006-9043-2

Fuchs, C., Aschenbruck, N., Martini, P., & Wieneke, M. (2011). Indoor tracking for mission critical scenarios: A survey. *Pervasive and Mobile Computing*, *7*(1), 1–15. doi:10.1016/j.pmcj.2010.07.001

Ghouaiel, N., Cieutat, J.-M., & Jessel, J.-P. (2013). Mobile Augmented Reality applications to discover new environments (pp. 423–427).

Grejner-Brzezinska, D. A., Czarnecka, K., Toth, C. K., Moafipoor, S., & Markiel, J. N. (2009). PERSONAL NAVIGATION: EXTENDING MOBILE MAPPING TECHNOLOGIES INTO INDOOR ENVIRONMENTS. *BOLETIM DE CIENCIAS GEODESICAS*, *15*(5), 790–806.

Groves, P. D., Pulford, G. W., Littlefield, C. A., Nash, D. L. ., & Mather, C. J. (2007). Inertial navigation versus pedestrian dead reckoning: Optimizing the integration (pp. 2043–2055).

Guivant, J., Masson, F., Nebot, E., & Nieto, J. (2004). Navigation and Mapping in Large Unstructured Environments. *The International Journal of Robotics Research*, *23*(4-5), 449–472. doi:10.1177/0278364904042203

Gusenbauer, D., Isert, C., & Kr s che, J. (2010). Self-contained indoor positioning on off-the-shelf mobile devices (pp. 1–9). IEEE. doi:10.1109/IPIN.2010.5646681

Haq, S., Hill, G., & Pramanik, A. (2005). Comparison of configurational, wayfinding and cognitive correlates in real and virtual settings (pp. 387–406).

Haque, S., Kulik, L., & Klippel, A. (2007). Algorithms for Reliable Navigation and Wayfinding, 308–326.

Hile, H., & Borriello, G. (2007). Information Overlay for Camera Phones in Indoor Environments. *Camera*, 68–84.

Ho, C., Bro, M., & Knauff, M. (2007). Up the down staircase : Wayfinding strategies in multi-level buildings, *26*(2006), 284–299. doi:10.1016/j.jenvp.2006.09.002

Hochmair, H. H. (n.d.). 1 PDA-Assisted Indoor-Navigation with Imprecise Positioning : Results of a Desktop Usability Study.

Hölscher, C., Meilinger, T., Vrachliotis, G., Brösamle, M., & Knauff, M. (2006). Up the down staircase: Wayfinding strategies in multi-level buildings. *Journal of Environmental Psychology*, *26*(4), 284–299. doi:10.1016/j.jenvp.2006.09.002

Hundelshausen, F., Luettel, T., & Wuensche, H.-J. (2011). Cognitive Navigation. *KI - Künstliche Intelligenz*, *25*(2), 125–132. doi:10.1007/s13218-011-0092-0

Hutchison, D., Kanade, T., Kittler, J., Kleinberg, J. M., Mattern, F., Mitchell, J. C., … Winstanley, A. C. (2009). Campus Guidance System for International Conferences Based on OpenStreetMap. In J. D. Carswell, A. S. Fotheringham, & G. McArdle (Eds.), (Vol. 5886, pp. 187–198). Berlin, Heidelberg: Springer Berlin Heidelberg.

Hyojeong Shin, Yohan Chon, & Hojung Cha. (2012). Unsupervised Construction of an Indoor Floor Plan Using a Smartphone. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, *42*(6), 889–898. doi:10.1109/TSMCC.2011.2169403

Ishikawa, T., Fujiwara, H., Imai, O., & Okabe, A. (2008). Wayfinding with a GPS-based mobile navigation system: A comparison with maps and direct experience. *Journal of Environmental Psychology*, *28*(1), 74–82.

Julier, S., Lanzagorta, M., Baillot, Y., Rosenblum, L., Feiner, S., Hollerer, T., & Sestito, S. (2000). Information filtering for mobile augmented reality (pp. 3–11). IEEE. doi:10.1109/ISAR.2000.880917

Kaiser, S., Khider, M., & Robertson, P. (2011). A human motion model based on maps for navigation systems. *EURASIP Journal on Wireless Communications and Networking*, *2011*(1), 60.

Kargl, F., Geßler, S., & Flerlage, F. (2007). The iNAV Indoor Navigation System. *Compass*, 110–117.

Kenn, H., Behrens, N., & Kleiner, A. (2007). Optimizing indoor PDR performance with self-deployed position markers (pp. 1–8). VDE.

Khalifa, S. (2013). Converting context to indoor position using built-in smartphone sensors (pp. 423–424). doi:10.1109/PerComW.2013.6529533

Kim, J., & Jun, H. (2008). Vision-Based Location Positioning using Augmented Reality for Indoor Navigation. *Interface*, *54*(3), 954–962.

Klann, M., & Geissler, M. (2012). experience prototyping: a new approach to designing Firefighter navigation Support, 4–8.

Klanten, R., Ehmann, S., Tissot, T. and N. Bourquin (Ed.) (2010). Data Flow 2: Visualizing Information in Graphic Design. Berlin, Gestalten.

Klingbeil, L., & Wark, T. (2008). A wireless sensor network for real-time indoor localisation and motion monitoring (pp. 39–50).

Klippel, A., Richter, K.-F., & Hansen, S. (2006). Wayfinding Choreme Maps. In S. Bres & R. Laurini (Eds.), (pp. 94–108). Springer Berlin Heidelberg.

Kloch, K., Lukowicz, P., & Fischer, C. (2011). Collaborative PDR Localisation with Mobile Phones.

Kothari, N., Kannan, B., & Dias, M. B. (2011). Robust Indoor Localization on a Commercial Smart-Phone. *Robotics*.

Koulouriotis, D., Amanatiadis, A., & Gasteratos, A. (2011). An intelligent multi-sensor system for first responder indoor navigation. *Measurement Science and Technology*, *22*(11), 114025. doi:10.1088/0957-0233/22/11/114025

Kourouthanassis, P. E., Giaglis, G. M., & Vrechopoulos, A. P. (2007). Enhancing user experience through pervasive information systems: The case of pervasive retailing. *International Journal of Information Management*, *27*(5), 319–335. doi:10.1016/j.ijinfomgt.2007.04.005

Levi, R. W., & Marshall, R. R. (n.d.). Navigation device for personnel on foot.

Li, C., & Willis, K. (2006). Modeling context aware interaction for wayfinding using mobile devices (pp. 97–100). New York, NY, USA: ACM. doi:10.1145/1152215.1152235

Li, H., & Giudice, N. A. (n.d.-a). Details-on-demand Mobile Visual Interface for Facilitating Indoor Wayfinding.

Libby, R. (2008). A simple method for reliable footstep detection on embedded sensor platforms, 1–16.

Link, J. A. B., Smith, P., & Wehrle, K. (2011). FootPath: Accurate Map-based Indoor Navigation Using Smartphones.

Liu, K., Liu, X., & Li, X. (2013). Guoguo: Enabling Fine-grained Indoor Localization via Smartphone (pp. 235–248). New York, NY, USA: ACM. doi:10.1145/2462456.2464450

Lovelace, K., Hegarty, M., & Montello, D. (1999). Elements of good route directions in familiar and unfamiliar environments. *Spatial information theory. Cognitive and computational foundations of geographic information science*, 751–751.

Lyardet, F., Szeto, D. W., & Aitenbichler, E. (2008). Context-Aware Indoor Navigation, 290–307.

Lynch, K., (1960). *The Image of the City.* s.l.:MIT Press.

McCandless, David. (2012). The Visual Miscellaneum: Revised and Reimagined. Harper Design, New York.

Mulloni, A., Wagner, D., Barakonyi, I., & Schmalstieg, D. (2009). Indoor Positioning and Navigation with Camera Phones. *IEEE Pervasive Computing*, *8*(2), 22–31. doi:10.1109/MPRV.2009.30

Najme, M., & Naqvi, Z. (n.d.). Step Counting Using Smartphone-Based Accelerometer, *4*(05), 675–681.

Narzt, W., Pomberger, G., Ferscha, A., Kolb, D., Müller, R., Wieghardt, J., … Lindinger, C. (2005). Augmented reality navigation systems. *Universal Access in the Information Society*, *4*(3), 177–187. doi:10.1007/s10209-005-0017-5

NMC Horizon Report > 2012 Higher Education Edition. (2012). *Higher Education*.

Of, O. (2011). Map-based Indoor People Localization using an Inertial Measurement Unit *, *1248*, 1233–1248.

Ojeda, L., & Borenstein, J. (2007). Non-GPS Navigation for Security Personnel and First Responders. *Journal of Navigation*, *60*(03), 391. doi:10.1017/S0373463307004286

Osborn, W., & Hinze, A. (n.d.). TIP-tree: A spatial index for traversing locations in context-aware mobile access to digital libraries. *Pervasive and Mobile Computing*. doi:10.1016/j.pmcj.2013.12.002

Passini, R. (1984). Spatial representations, a wayfinding perspective. *Journal of environmental psychology*, *4*(2), 153–164.

Pinto, F. H. ., & others. (2012). An indoor localization solution for mobile devices.

Pombinho, P., Afonso, A. P., & Carmo, M. B. (2010). Indoor Positioning Using a Mobile Phone with an Integrated Accelerometer and Digital Compass, 443–446.

Qualifying, A. M., & Report, P. (2009). Indoor Navigation System for Handheld Devices. *System*.

Retscher, G., & Kealy, A. (2005). Ubiquitous Positioning Technologies for Modern Intelligent Navigation Systems. *Journal of Navigation*, *59*(01), 91. doi:10.1017/S0373463305003504

Rodrigues, Joel J P C, Lopes, I. M. C., Silva, B. M. C., & Torre, I. D. La. (2013). A new mobile ubiquitous computing application to control obesity: SapoFit. *Informatics for health & social care*, *38*(1), 37–53. doi:10.3109/17538157.2012.674586

Rodrigues, Joel J. P. C., Lopes, I. M. C., Silva, B. M. C., & Torre, I. de La. (2013). A new mobile ubiquitous computing application to control obesity: SapoFit. *Informatics for Health and Social Care*, *38*(1), 37–53. doi:10.3109/17538157.2012.674586

Roongpiboonsopit, D., Kasemsuppakorn, P., & Karimi, H. A. (2011). Uncertainty in Personal Navigation Services. *JOURNAL OF NAVIGATION*, *64*(2), 341–356. doi:10.1017/S037346331000055X

Santos, A. C., Tarrataca, L., & Cardoso, J. M. P. (2010). The Feasibility of Navigation Algorithms on Smartphones using J2ME. *Mobile Networks and Applications*, *15*(6), 819–830. doi:10.1007/s11036-010-0236-8

Saunders, Mark NK, et al. *Research methods for business students, 5/e*. Prentice Hall 2009

Schneiderman B., Plaisant, C., (2009). *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Addison-Wesley.

Schwabe, G., & Göth, C. (n.d.). Navigating and interacting indoors with a mobile learning game. *Design*.

Science, S. M. C., Engineering, B. S. E., Science, C., Balakrishnan, H., Supervisor, T., & Smith, A. C. (2005). The Cricket Indoor Location System, (2001).

Šegvi, S., Remazeilles, A., Chaumette, F., & Diosi, A. (2009). A mapping and localization framework for scalable appearance-based navigation. *Computer Vision and Image Understanding*, *113*(2), 172–187. doi:10.1016/j.cviu.2008.08.005

Shahrom, M. (2013). Relative and cardinal directions for privacy-aware personal navigation services: A comparison towards navigation efficiency (pp. 426–431). doi:10.1109/ISSNIP.2013.6529828

Shin, S. H., Lee, M. S., Park, C. G., & Hong, H. S. (2010). Pedestrian dead reckoning system with phone location awareness algorithm (pp. 97–101).

Shin, S. H., Park, C. G., Kim, J. W., Hong, H. S., & Lee, J. M. (2007). Adaptive step length estimation algorithm using low-cost MEMS inertial sensors (pp. 1–5).

Skorupka, A. (2008). Do you know your way? A mixed-method study on the use of virtual environments in wayfinding research. *Movement and Orientation in Built Environments: Evaluating Design Rationale and User Cognition*, 21.

Skorupka, A. (2009). Comparing Human Wayfinding Behavior in Real and Virtual Environment (p. 104).

Smith, F. (2011). Taking QR Codes to the Park. *Information Today*, (February).

Statement, P., & Overview, A. (n.d.). Algorithmic Compositional Tool using Encryption – Synopsis, 1–25.

Succi, G., Clapp, D., Gampert, R., & Prado, G. (2001). Footstep Detection and Tracking. *Sensors (Peterborough, NH)*, *4393*, 22–29.

Takeuchi, Y., & Perlin, K. (2012). ClayVision: the (elastic) image of the city (pp. 2411–2420). New York, NY, USA: ACM. doi:10.1145/2207676.2208404

Thrun, S. (1998). Artificial Intelligence Learning metric-topological maps for indoor mobile robot navigation ’. *Artificial Intelligence*, *99*, 21–71.

Tinto, V. (1988). Stages of Student Departure: Reflections on the Longitudinal Character of Student Leaving. *The Journal of Higher Education*, *59*(4), 438–455.

Toth, C. K., Markiel, J. N., Moafipoor, S., Czarnecka, K., Positioning, S., & State, T. O. (n.d.). Personal Navigation : Extending Mobile Mapping Techonologies Into Indoor, 790–806.

Victorino, A. C., Rives, P., & Borrelly, J.-J. (2003). Safe Navigation for Indoor Mobile Robots. Part II: Exploration, Self-Localization and Map Building. *The International Journal of Robotics Research*, *22*(12), 1019–1039.

Voicu, H. (1992). Exploration , Navigation and Cognitive Mapping, (1932), 207–223.

Voicu, H., & Schmajuk, N. (2000). Exploration, Navigation and Cognitive Mapping. *Adaptive Behavior*, *8*(3-4), 207–223. doi:10.1177/105971230000800301

Wang, H., Lenz, H., Szabo, A., & Bamberger, J. (n.d.). Enhancing the Map Usage for Indoor Location-Aware Systems, 151–160.

Weiser, M., 1991. The computer for the twenty-first century. *ScientificAmerican*, 256(3), p. 94–104.

Weiss, Mark Allen. *Data Structures and Algorithms 2/e*. Addison Wesley, 1999.

Ying Zhang, Ackerson, L., Duff, D., Eldershaw, C., & Yim, M. (2004). STAM: a system of tracking and mapping in real environments. *IEEE Wireless Communications*, *11*(6), 87– 96. doi:10.1109/MWC.2004.1368901

Zhang, H., & Zhao, Y. (2011). The performance comparison and analysis of extended Kalman filters for GPS/DR navigation. *Optik - International Journal for Light and Electron Optics*, *122*(9), 777–781. doi:10.1016/j.ijleo.2010.05.023

Zipf, A., & Goetz, M. (2011). Formal definition of a user-adaptive and length-optimal routing graph for complex indoor environments. *Geo-spatial Information Science*, *14*(2), 119–128. doi:10.1007/s11806-011-0474-3

Appendix A – Smartphone Questionnaires

A.1. The First Questionnaire

Please answer the following questions.

1. Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app)
    a. Yes
    b. No

2. If you use a smartphone, what is its manufacturer brand?
    a. Apple
    b. HTC
    c. Samsung
    d. Blackberry
    e. Nokia
    f. LG
    g. Sony Ericsson
    h. Other [please specify]
    i. Don't Know

3. If you use a smartphone, what operating system does it run?
    a. Apple OS
    b. Android
    c. Windows Phone 7
    d. Blackberry
    e. Symbian
    f. Other [please specify]
    g. Don't Know

4. If you use an Android smartphone, what version of Android does it run?
    a. Android 2.1 or earlier
    b. Froyo, Android 2.2
    c. Gingerbread, Android 2.3
    d. Ice Cream Sandwich, Android 4.0
    e. Other [please specify]
    f. Don't know

5. If you use an Apple iPhone, what version of the operating system does it run?
    a. Version 3.x
    b. Version 4.x
    c. Version 5.x
    d. Don't know
    e. Other [please specify]

6. If you use a smartphone, please indicate how much you use it to do the following:

	Several times per day	Once per day	Several times per week	Monthly	Never
Accessing Social Networks					
Using Apps to Access Info					
Performing Web Searches					
Gaming					
Watching Videos					
Listening to Audio/Radio					
Taking Photos					
Map Navigation & Directions					
Downloading & Installing Apps					
Web Browsing					

7. If you use a smartphone, what type of mobile operator plan do you have with your smartphone?
    a. Pre-pay
    b. Post-pay
    c. Don't know

8. If you use a smartphone, please indicate how important the following features are to you:

	Very Important	Important	Neutral	Not so Important	Not at all Important
Accessing Social					

Networks					
Using Apps to Access Info					
Performing Web Searches					
Gaming					
Watching Videos					
Listening to Audio/Radio					
Taking Photos					
Map Navigation & Directions					
Downloading & Installing Apps					
Web Browsing					

9. If you DO NOT use a smartphone, do you intend to get a smartphone in the next year?
    a. Yes – in the next 6 months
    b. Yes – in the next 12 months
    c. No
    d. Don't know

10. If you DO NOT use a smartphone and intend to get a smartphone in the next year, please indicate how important the following features are to you:

	Very Important	Important	Neutral	Not so Important	Not at all Important
Accessing Social Networks					
Using Apps to Access Info					
Performing Web Searches					
Gaming					
Watching Videos					
Listening to Audio/Radio					

Taking Photos					
Map Navigation & Directions					
Downloading & Installing Apps					
Web Browsing					

11. Please indicate how often you use the following sources to access information about the University?
(Please tick all that apply)

	Never	Monthly	Several times per week	Once per day	Several times per day
University Website					
Notice Boards					
Social Networks					
Contact with Student Union					
First 7 weeks programme - online					
First 7 weeks programme - offline					
Word of Mouth					

12. For the following types of University information, please indicate how important each one is to you during your first year of college:

	Not at all Important	Not so Important	Neutral	Important	Very Important
Campus Directions					
Facilities Guidance & Info					
Offers & Deals Info					
Entertainment & Social Info					

Lifestyle Guidance & Info					
Academic Guidance & Info					
Career Guidance & Info					
Skills Guidance & Info					

13. For the following types of University information, if a university mobile app existed, please indicate how likely you would be to use such a mobile app to access the information, presuming you had a smartphone:

	Very Likely	Likely	Neutral	Not so Likely	Not at all Likely
Campus Directions					
Facilities Guidance & Info					
Offers & Deals Info					
Entertainment & Social Info					
Lifestyle Guidance & Info					
Academic Guidance & Info					
Career Guidance & Info					
Skills Guidance & Info					

14. What type of student are you?
    a. Undergraduate
    b. Postgraduate

15. In which year are you studying?
    a. 1^{st} year
    b. 2^{nd} year
    c. 3^{rd} year
    d. 4^{th} year
    e. Other [please specify]

16. Are you 18 years of age or over?
    a. Yes
    b. No

17. In which discipline are you studying?
    a. Business
    b. Arts, Humanities & Social Science
    c. Education
    d. Health Sciences
    e. Engineering
    f. Science
    g. Other [please specify]
    h. Don't Know

18. Please enter any comments that you have about this survey.

A.2. Research Ethics Information and Consent Sheet

EMAIL QUESTIONNAIRE INFORMATION & CONSENT SHEET

Are you a first year student studying at the University of Limerick?

If so, I would like to invite you to complete this short questionnaire about smartphone usage among first year students. I am an MSc student conducting research in this area.

This short questionnaire will take no longer than 5 minutes and is completely anonymous.

By clicking on the questionnaire link below you consent to participate in this research project, however you are free to withdraw from the questionnaire at any time.

LINK TO ONLINE QUESTIONNAIRE TO BE ENTERED HERE

Questions or concerns regarding this research project can be sent to the primary investigator and researcher Daryl Feehely (daryl.feehely@ul.ie), to the research project supervisor Mikael Fernström (mikael.fernstrom@ul.ie), to the Centre for Teaching & Learning (maura.murphy@ul.ie) or to the Science & Engineering Research Ethics Committee Chairperson (SciEngEthics@ul.ie).

FIRST SEVEN WEEKS MOBILE APP INFORMATION & CONSENT

DISCLAIMER SCREEN

Are you a first year student, over the age of 18, studying at the University of Limerick?

If so, I would like to invite you to participate in a research project about smartphone usage among first year students that are 18 years of age or older.

By selecting the "OPT IN" option below you certify that you are 18 years of age or old, and that you consent to allowing anonymous usage metrics from this app be analysed as part of the research project.

You may withdraw your participation at any time by accessing this screen through the menu system and selecting "OPT OUT".

OPT IN (I am 18 years of age or older) - ☐

OPT OUT - ☐

IN WHICH DISCIPLINE ARE YOU STUDYING? – [LIST OF DISCIPLINES]

Questions or concerns regarding this research project can be sent to the primary investigator and researcher Daryl Feehely (daryl.feehely@ul.ie), to the research project supervisor Mikael Fernström (mikael.fernstrom@ul.ie), to the Centre for Teaching & Learning (maura.murphy@ul.ie) or to the Science & Engineering Research Ethics Committee Chairperson (SciEngEthics@ul.ie).

A.3. The First Questionnaire Results

A.3.1. Results Data

In which year are you studying?

Are you 18 years of age or over?			Frequency	Percent	Valid Percent	Cumulative Percent
a.Yes	Valid	Other (please specify)	3	1.6	1.6	1.6
		a.1st year	179	95.2	95.2	96.8
		b.2nd year	1	.5	.5	97.3
		c.3rd year	4	2.1	2.1	99.5
		d.4th year	1	.5	.5	100.0
		Total	188	100.0	100.0	

Table 1. First Questionnaire Results - Year of Study

In which discipline are you studying?

Are you 18 years of age or over?			Frequency	Percent	Valid Percent	Cumulative Percent
a.Yes	Valid	a.Business	26	14.5	14.5	14.5
		b.Arts, Humanities & Social Science	37	20.7	20.7	35.2
		c.Education	19	10.6	10.6	45.8
		d.Health Sciences	19	10.6	10.6	56.4
		e.Engineering	36	20.1	20.1	76.5
		f.Science	34	19.0	19.0	95.5
		g.Other [please specify]	8	4.5	4.5	100.0
		Total	179	100.0	100.0	

Table 2. First Questionnaire Results - Study Discipline

Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app)					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	137	76.5	76.5	76.5
	no	42	23.5	23.5	100.0
	Total	179	100.0	100.0	

Table 3. First Questionnaire Results - Smartphone Usage

What is its manufacturer brand?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	a.Apple	45	32.8	32.8	32.8
	b.HTC	23	16.8	16.8	49.6
	c.Samsung	37	27.0	27.0	76.6
	d.Blackberry	15	10.9	10.9	87.6
	e.Nokia	7	5.1	5.1	92.7
	g.Sony Ericsson	10	7.3	7.3	100.0
	Total	137	100.0	100.0	

Table 4. First Questionnaire Results - Smartphone Manufacturer

What operating system does it run?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Other (please specify)	1	.7	.7	.7
	a.Apple OS	45	32.8	32.8	33.6
	b.Android	63	46.0	46.0	79.6
	c.Windows Phone 7	3	2.2	2.2	81.8
	d.Blackberry	14	10.2	10.2	92.0
	e.Symbian	1	.7	.7	92.7
	f.Don't Know	10	7.3	7.3	100.0
	Total	137	100.0	100.0	

Table 5. First Questionnaire Results - Smartphone Operating System

If you use an Android smartphone, what version of Android does it run?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Other (please specify)	2	1.5	1.8	1.8
	a. Android 2.1 or earlier	11	8.0	9.9	11.7
	b. Froyo, Android 2.2	14	10.2	12.6	24.3
	c. Gingerbread, Android 2.3	15	10.9	13.5	37.8
	d. Ice Cream Sandwich, Android 4.0	6	4.4	5.4	43.2
	e. Don't know	25	18.2	22.5	65.8
	f. I don't use an Android Smartphone	38	27.7	34.2	100.0
	Total	111	81.0	100.0	
Missing	System	26	19.0		
Total		137	100.0		

Other (please specify)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		135	98.5	98.5	98.5
	Custom Rom Cyanogen 7 Based on 2.3.4	1	.7	.7	99.3
	iPhone	1	.7	.7	100.0
	Total	137	100.0	100.0	

If you use an Apple iPhone, what version of the operating system does it run?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Other (please specify)	1	.7	.9	.9
	a. Version 3.x	4	2.9	3.6	4.5
	b. Version 4.x	8	5.8	7.1	11.6
	c. Version 5.x	25	18.2	22.3	33.9
	d. Don't know	8	5.8	7.1	41.1
	e. I don't use an Apple iPhone	66	48.2	58.9	100.0
	Total	112	81.8	100.0	
Missing	System	25	18.2		
Total		137	100.0		

Other (please specify)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		136	99.3	99.3	99.3
	IOS5	1	.7	.7	100.0
	Total	137	100.0	100.0	

Table 6. First Questionnaire Results - Android & iOS OS Versions

What type of mobile operator plan do you have with your smartphone?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	a.Pre-pay	97	70.8	71.9	71.9
	b.Post-pay	35	25.5	25.9	97.8
	c.Don't know	3	2.2	2.2	100.0
	Total	135	98.5	100.0	
Missing	System	2	1.5		
Total		137	100.0		

Table 7. First Questionnaire Results - Mobile Operator Plan

Web Browsing					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	72	52.6	52.6	52.6
	Once per day	15	10.9	10.9	63.5
	Several times per week	24	17.5	17.5	81.0
	Monthly	12	8.8	8.8	89.8
	Never	14	10.2	10.2	100.0
	Total	137	100.0	100.0	

Table 8. First Questionnaire Results - Feature Usage - Web Browsing

Downloading & Installing Apps					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	6	4.4	4.4	4.4
	Once per day	9	6.6	6.6	11.0
	Several times per week	54	39.4	39.7	50.7
	Monthly	56	40.9	41.2	91.9
	Never	11	8.0	8.1	100.0
	Total	136	99.3	100.0	
Missing	System	1	.7		
Total		137	100.0		

Table 9. First Questionnaire Results - Feature Usage - Downloading & Installing Apps

Map Navigation & Directions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	5	3.6	3.7	3.7
	Once per day	9	6.6	6.6	10.3
	Several times per week	24	17.5	17.6	27.9
	Monthly	57	41.6	41.9	69.9
	Never	41	29.9	30.1	100.0
	Total	136	99.3	100.0	
Missing	System	1	.7		
Total		137	100.0		

Table 10. First Questionnaire Results - Feature Usage - Map Navigation & Directions

Taking Photos

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	30	21.9	22.1	22.1
	Once per day	20	14.6	14.7	36.8
	Several times per week	50	36.5	36.8	73.5
	Monthly	29	21.2	21.3	94.9
	Never	7	5.1	5.1	100.0
	Total	136	99.3	100.0	
Missing	System	1	.7		
Total		137	100.0		

Table 11. First Questionnaire Results - Feature Usage - Taking Photos

Listening to Audio/Radio					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	35	25.5	25.9	25.9
	Once per day	20	14.6	14.8	40.7
	Several times per week	29	21.2	21.5	62.2
	Monthly	22	16.1	16.3	78.5
	Never	29	21.2	21.5	100.0
	Total	135	98.5	100.0	
Missing	System	2	1.5		
Total		137	100.0		

Table 12. First Questionnaire Results - Feature Usage - Listening to Audio/Radio

Watching Videos					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	16	11.7	11.9	11.9
	Once per day	22	16.1	16.4	28.4
	Several times per week	33	24.1	24.6	53.0
	Monthly	36	26.3	26.9	79.9
	Never	27	19.7	20.1	100.0
	Total	134	97.8	100.0	
Missing	System	3	2.2		
Total		137	100.0		

Table 13. First Questionnaire Results - Feature Usage - Watching Videos

Gaming					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	24	17.5	18.0	18.0
	Once per day	15	10.9	11.3	29.3
	Several times per week	19	13.9	14.3	43.6
	Monthly	39	28.5	29.3	72.9
	Never	36	26.3	27.1	100.0
	Total	133	97.1	100.0	
Missing	System	4	2.9		
Total		137	100.0		

Table 14. First Questionnaire Results - Feature Usage - Gaming

Performing Web Searches					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	67	48.9	48.9	48.9
	Once per day	18	13.1	13.1	62.0
	Several times per week	33	24.1	24.1	86.1
	Monthly	9	6.6	6.6	92.7
	Never	10	7.3	7.3	100.0
	Total	137	100.0	100.0	

Table 15. First Questionnaire Results - Feature Usage - Performing Web Searches

Using Apps to Access Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	60	43.8	44.8	44.8
	Once per day	21	15.3	15.7	60.4
	Several times per week	27	19.7	20.1	80.6
	Monthly	10	7.3	7.5	88.1
	Never	16	11.7	11.9	100.0
	Total	134	97.8	100.0	
Missing	System	3	2.2		
Total		137	100.0		

Table 16. First Questionnaire Results - Feature Usage - Using Apps to Access Info

Accessing Social Networks					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	80	58.4	58.4	58.4
	Once per day	13	9.5	9.5	67.9
	Several times per week	20	14.6	14.6	82.5
	Monthly	7	5.1	5.1	87.6
	Never	17	12.4	12.4	100.0
	Total	137	100.0	100.0	

Table 17. First Questionnaire Results – Feature Usage - Accessing Social Networks

Web Browsing					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	70	51.1	51.5	51.5
	Important	44	32.1	32.4	83.8
	Neutral	13	9.5	9.6	93.4
	Not so Important	4	2.9	2.9	96.3
	Not at all Important	5	3.6	3.7	100.0
	Total	136	99.3	100.0	
Missing	System	1	.7		
Total		137	100.0		

Table 18. First Questionnaire Results - Feature Importance - Web Browsing

Downloading & Installing Apps					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	39	28.5	28.7	28.7
	Important	53	38.7	39.0	67.6
	Neutral	27	19.7	19.9	87.5
	Not so Important	9	6.6	6.6	94.1
	Not at all Important	8	5.8	5.9	100.0
	Total	136	99.3	100.0	
Missing	System	1	.7		
Total		137	100.0		

Table 19. First Questionnaire Results - Feature Importance - Installing Apps

Map Navigation & Directions

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	27	19.7	19.7	19.7
	Important	45	32.8	32.8	52.6
	Neutral	40	29.2	29.2	81.8
	Not so Important	16	11.7	11.7	93.4
	Not at all Important	9	6.6	6.6	100.0
	Total	137	100.0	100.0	

Table 20. First Questionnaire Results - Feature Importance - Map Navigation & Directions

Taking Photos

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	57	41.6	41.6	41.6
	Important	48	35.0	35.0	76.6
	Neutral	15	10.9	10.9	87.6
	Not so Important	13	9.5	9.5	97.1
	Not at all Important	4	2.9	2.9	100.0
	Total	137	100.0	100.0	

Table 21. First Questionnaire Results - Feature Importance - Taking Photos

Listening to Audio/Radio

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	39	28.5	29.1	29.1
	Important	46	33.6	34.3	63.4
	Neutral	23	16.8	17.2	80.6
	Not so Important	12	8.8	9.0	89.6
	Not at all Important	14	10.2	10.4	100.0
	Total	134	97.8	100.0	
Missing	System	3	2.2		
Total		137	100.0		

Table 22. First Questionnaire Results - Feature Importance - Listening to Audio/Radio

Watching Videos					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	22	16.1	16.3	16.3
	Important	48	35.0	35.6	51.9
	Neutral	34	24.8	25.2	77.0
	Not so Important	15	10.9	11.1	88.1
	Not at all Important	16	11.7	11.9	100.0
	Total	135	98.5	100.0	
Missing	System	2	1.5		
Total		137	100.0		

Table 23. First Questionnaire Results - Feature Importance - Watching Videos

Gaming					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	19	13.9	13.9	13.9
	Important	29	21.2	21.2	35.0
	Neutral	28	20.4	20.4	55.5
	Not so Important	32	23.4	23.4	78.8
	Not at all Important	29	21.2	21.2	100.0
	Total	137	100.0	100.0	

Table 24. First Questionnaire Results - Feature Importance - Gaming

Performing Web Searches					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	66	48.2	48.5	48.5
	Important	50	36.5	36.8	85.3
	Neutral	11	8.0	8.1	93.4
	Not so Important	7	5.1	5.1	98.5
	Not at all Important	2	1.5	1.5	100.0
	Total	136	99.3	100.0	
Missing	System	1	.7		
Total		137	100.0		

Table 25. First Questionnaire Results - Feature Importance - Performing Web Searches

Using Apps to Access Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	55	40.1	40.4	40.4
	Important	40	29.2	29.4	69.9
	Neutral	24	17.5	17.6	87.5
	Not so Important	12	8.8	8.8	96.3
	Not at all Important	5	3.6	3.7	100.0
	Total	136	99.3	100.0	
Missing	System	1	.7		
Total		137	100.0		

Table 26. First Questionnaire Results - Feature Importance - Using Apps to Access Info

Accessing Social Networks					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	61	44.5	44.5	44.5
	Important	41	29.9	29.9	74.5
	Neutral	11	8.0	8.0	82.5
	Not so Important	12	8.8	8.8	91.2
	Not at all Important	12	8.8	8.8	100.0
	Total	137	100.0	100.0	

Table 27. First Questionnaire Results - Feature Importance - Accessing Social Networks

Do you intend to get a smartphone in the next year?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	a.Yes - in the next 6 months	25	18.2	19.7	19.7
	b.Yes - in the next 12 months	22	16.1	17.3	37.0
	c.No	56	40.9	44.1	81.1
	d.Don't know	24	17.5	18.9	100.0
	Total	127	92.7	100.0	
Missing	System	10	7.3		
Total		137	100.0		

Table 28. First Questionnaire Results - Smartphone owners - intention to get a smartphone

Do you intend to get a smartphone in the next year?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	a.Yes - in the next 6 months	7	16.7	16.7	16.7
	b.Yes - in the next 12 months	6	14.3	14.3	31.0
	c.No	17	40.5	40.5	71.4
	d.Don't know	12	28.6	28.6	100.0
	Total	42	100.0	100.0	

Table 29. First Questionnaire Results - No Smartphone: Intention on getting a smartphone

Web Browsing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	11	26.2	40.7	40.7
	Important	11	26.2	40.7	81.5
	Neutral	2	4.8	7.4	88.9
	Not so Important	1	2.4	3.7	92.6
	Not at all Important	2	4.8	7.4	100.0
	Total	27	64.3	100.0	
Missing	System	15	35.7		
Total		42	100.0		

Table 30. First Questionnaire Results - No Smartphone: Feature Importance - Web Browsing

Downloading & Installing Apps

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	6	4.4	4.4	4.4
	Once per day	9	6.6	6.6	11.0
	Several times per week	54	39.4	39.7	50.7
	Monthly	56	40.9	41.2	91.9
	Never	11	8.0	8.1	100.0
	Total	136	99.3	100.0	
Missing	System	1	.7		
Total		137	100.0		

Table 31. First Questionnaire Results - No Smartphone: Feature Importance - Downloading & Installing Apps

Map Navigation & Directions					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	5	11.9	18.5	18.5
	Important	7	16.7	25.9	44.4
	Neutral	8	19.0	29.6	74.1
	Not so Important	3	7.1	11.1	85.2
	Not at all Important	4	9.5	14.8	100.0
	Total	27	64.3	100.0	
Missing	System	15	35.7		
Total		42	100.0		

Table 32. First Questionnaire Results - No Smartphone: Feature Importance - Map Navigation & Directions

Taking Photos					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	12	28.6	44.4	44.4
	Important	10	23.8	37.0	81.5
	Neutral	2	4.8	7.4	88.9
	Not so Important	2	4.8	7.4	96.3
	Not at all Important	1	2.4	3.7	100.0
	Total	27	64.3	100.0	
Missing	System	15	35.7		
Total		42	100.0		

Table 33. First Questionnaire Results - No Smartphone: Feature Importance - Taking Photos

Listening to Audio/Radio					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	12	28.6	44.4	44.4
	Important	7	16.7	25.9	70.4
	Neutral	3	7.1	11.1	81.5
	Not so Important	4	9.5	14.8	96.3
	Not at all Important	1	2.4	3.7	100.0
	Total	27	64.3	100.0	
Missing	System	15	35.7		
Total		42	100.0		

Table 34. First Questionnaire Results - No Smartphone: Feature Importance - Listening to Audio/Radio

Watching Videos					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	4	9.5	14.8	14.8
	Important	9	21.4	33.3	48.1
	Neutral	5	11.9	18.5	66.7
	Not so Important	5	11.9	18.5	85.2
	Not at all Important	4	9.5	14.8	100.0
	Total	27	64.3	100.0	
Missing	System	15	35.7		
Total		42	100.0		

Table 35. First Questionnaire Results - No Smartphone: Feature Importance - Watching Videos

Gaming					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	2	4.8	7.4	7.4
	Important	6	14.3	22.2	29.6
	Neutral	6	14.3	22.2	51.9
	Not so Important	6	14.3	22.2	74.1
	Not at all Important	7	16.7	25.9	100.0
	Total	27	64.3	100.0	
Missing	System	15	35.7		
Total		42	100.0		

Table 36. First Questionnaire Results - No Smartphone: Feature Importance - Gaming

Performing Web Searches					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	10	23.8	37.0	37.0
	Important	11	26.2	40.7	77.8
	Neutral	4	9.5	14.8	92.6
	Not at all Important	2	4.8	7.4	100.0
	Total	27	64.3	100.0	
Missing	System	15	35.7		
Total		42	100.0		

Table 37. First Questionnaire Results - No Smartphone: Feature Importance - Performing Web Searches

Using Apps to Access Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	6	14.3	22.2	22.2
	Important	11	26.2	40.7	63.0
	Neutral	5	11.9	18.5	81.5
	Not so Important	2	4.8	7.4	88.9
	Not at all Important	3	7.1	11.1	100.0
	Total	27	64.3	100.0	
Missing	System	15	35.7		
Total		42	100.0		

Table 38. First Questionnaire Results - No Smartphone: Feature Importance - Using Apps to Access Info

Accessing Social Networks					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	8	19.0	29.6	29.6
	Important	9	21.4	33.3	63.0
	Neutral	4	9.5	14.8	77.8
	Not so Important	2	4.8	7.4	85.2
	Not at all Important	4	9.5	14.8	100.0
	Total	27	64.3	100.0	
Missing	System	15	35.7		
Total		42	100.0		

Table 39. First Questionnaire Results - No Smartphone: Feature Importance - Accessing Social Networks

Word of Mouth					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	15	8.4	8.7	8.7
	Monthly	15	8.4	8.7	17.3
	Several times per week	58	32.4	33.5	50.9
	Once per day	30	16.8	17.3	68.2
	Several times per day	55	30.7	31.8	100.0
	Total	173	96.6	100.0	
Missing	System	6	3.4		
Total		179	100.0		

Table 40. First Questionnaire Results - University Information Sources Usage - Word of Mouth

First 7 weeks programme - offline					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	134	74.9	78.8	78.8
	Monthly	21	11.7	12.4	91.2
	Several times per week	9	5.0	5.3	96.5
	Once per day	5	2.8	2.9	99.4
	Several times per day	1	.6	.6	100.0
	Total	170	95.0	100.0	
Missing	System	9	5.0		
Total		179	100.0		

Table 41. First Questionnaire Results - University Information Sources Usage - F7W Offline

First 7 weeks programme - online					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	121	67.6	70.3	70.3
	Monthly	26	14.5	15.1	85.5
	Several times per week	17	9.5	9.9	95.3
	Once per day	6	3.4	3.5	98.8
	Several times per day	2	1.1	1.2	100.0
	Total	172	96.1	100.0	
Missing	System	7	3.9		
Total		179	100.0		

Table 42. First Questionnaire Results - University Information Sources Usage - F7W Online

Contact with Student Union					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	93	52.0	54.1	54.1
	Monthly	55	30.7	32.0	86.0
	Several times per week	18	10.1	10.5	96.5
	Once per day	6	3.4	3.5	100.0
	Total	172	96.1	100.0	
Missing	System	7	3.9		
Total		179	100.0		

Table 43. First Questionnaire Results - University Information Sources Usage - Students Union Contact

Social Networks					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	22	12.3	12.7	12.7
	Monthly	19	10.6	11.0	23.7
	Several times per week	39	21.8	22.5	46.2
	Once per day	36	20.1	20.8	67.1
	Several times per day	57	31.8	32.9	100.0
	Total	173	96.6	100.0	
Missing	System	6	3.4		
Total		179	100.0		

Table 44. First Questionnaire Results - University Information Sources Usage - Social Networks

Notice Boards					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	80	44.7	47.1	47.1
	Monthly	41	22.9	24.1	71.2
	Several times per week	31	17.3	18.2	89.4
	Once per day	14	7.8	8.2	97.6
	Several times per day	4	2.2	2.4	100.0
	Total	170	95.0	100.0	
Missing	System	9	5.0		
Total		179	100.0		

Table 45. First Questionnaire Results - University Information Sources Usage - Notice Boards

University Website					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never	13	7.3	7.5	7.5
	Monthly	49	27.4	28.2	35.6
	Several times per week	60	33.5	34.5	70.1
	Once per day	30	16.8	17.2	87.4
	Several times per day	22	12.3	12.6	100.0
	Total	174	97.2	100.0	
Missing	System	5	2.8		
Total		179	100.0		

Table 46. First Questionnaire Results - University Information Sources Usage - University Website

Skills Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all Important	5	2.8	2.9	2.9
	Not so Important	18	10.1	10.3	13.1
	Neutral	42	23.5	24.0	37.1
	Important	65	36.3	37.1	74.3
	Very Important	45	25.1	25.7	100.0
	Total	175	97.8	100.0	
Missing	System	4	2.2		
Total		179	100.0		

Table 47. First Questionnaire Results - University Information Importance - Skills Guidance & Info

Career Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all Important	7	3.9	4.0	4.0
	Not so Important	17	9.5	9.7	13.7
	Neutral	39	21.8	22.3	36.0
	Important	61	34.1	34.9	70.9
	Very Important	51	28.5	29.1	100.0
	Total	175	97.8	100.0	
Missing	System	4	2.2		
Total		179	100.0		

Table 48. First Questionnaire Results - University Information Importance - Career Guidance & Info

Academic Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not so Important	6	3.4	3.4	3.4
	Neutral	20	11.2	11.4	14.9
	Important	76	42.5	43.4	58.3
	Very Important	73	40.8	41.7	100.0
	Total	175	97.8	100.0	
Missing	System	4	2.2		
Total		179	100.0		

Table 49. First Questionnaire Results - University Information Importance - Academic Guidance & Info

Lifestyle Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all Important	15	8.4	8.6	8.6
	Not so Important	15	8.4	8.6	17.1
	Neutral	50	27.9	28.6	45.7
	Important	57	31.8	32.6	78.3
	Very Important	38	21.2	21.7	100.0
	Total	175	97.8	100.0	
Missing	System	4	2.2		
Total		179	100.0		

Table 50. First Questionnaire Results - University Information Importance - Lifestyle Guidance & Info

Entertainment & Social Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all Important	14	7.8	8.0	8.0
	Not so Important	8	4.5	4.6	12.6
	Neutral	30	16.8	17.1	29.7
	Important	72	40.2	41.1	70.9
	Very Important	51	28.5	29.1	100.0
	Total	175	97.8	100.0	
Missing	System	4	2.2		
Total		179	100.0		

Table 51. First Questionnaire Results - University Information Importance - Entertainment & Social Info

Offers & Deals Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all Important	10	5.6	5.7	5.7
	Not so Important	18	10.1	10.3	16.1
	Neutral	52	29.1	29.9	46.0
	Important	53	29.6	30.5	76.4
	Very Important	41	22.9	23.6	100.0
	Total	174	97.2	100.0	
Missing	System	5	2.8		
Total		179	100.0		

Table 52. First Questionnaire Results - University Information Importance - Offers & Deals Info

Facilities Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all Important	7	3.9	4.0	4.0
	Not so Important	8	4.5	4.6	8.7
	Neutral	27	15.1	15.6	24.3
	Important	68	38.0	39.3	63.6
	Very Important	63	35.2	36.4	100.0
	Total	173	96.6	100.0	
Missing	System	6	3.4		
Total		179	100.0		

Table 53. First Questionnaire Results - University Information Importance - Facilities Guidance & Info

Campus Directions					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all Important	9	5.0	5.1	5.1
	Not so Important	8	4.5	4.6	9.7
	Neutral	14	7.8	8.0	17.7
	Important	64	35.8	36.6	54.3
	Very Important	80	44.7	45.7	100.0
	Total	175	97.8	100.0	
Missing	System	4	2.2		
Total		179	100.0		

Table 54. First Questionnaire Results - University Information Importance - Campus Directions

Skills Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Likely	47	26.3	27.3	27.3
	Likely	45	25.1	26.2	53.5
	Neutral	44	24.6	25.6	79.1
	Not so Likely	22	12.3	12.8	91.9
	Not at all Likely	14	7.8	8.1	100.0
	Total	172	96.1	100.0	
Missing	System	7	3.9		
Total		179	100.0		

Table 55. First Questionnaire Results - University App Feature Usage Likeliness - Skills Guidance

Career Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Likely	54	30.2	31.0	31.0
	Likely	43	24.0	24.7	55.7
	Neutral	46	25.7	26.4	82.2
	Not so Likely	20	11.2	11.5	93.7
	Not at all Likely	11	6.1	6.3	100.0
	Total	174	97.2	100.0	
Missing	System	5	2.8		
Total		179	100.0		

Table 56. First Questionnaire Results - University App Feature Usage Likeliness - Career Guidance

Academic Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Likely	68	38.0	39.1	39.1
	Likely	55	30.7	31.6	70.7
	Neutral	33	18.4	19.0	89.7
	Not so Likely	12	6.7	6.9	96.6
	Not at all Likely	6	3.4	3.4	100.0
	Total	174	97.2	100.0	
Missing	System	5	2.8		
Total		179	100.0		

Table 57. First Questionnaire Results - University App Feature Usage Likeliness - Academic Guidance

Lifestyle Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Likely	59	33.0	34.1	34.1
	Likely	42	23.5	24.3	58.4
	Neutral	41	22.9	23.7	82.1
	Not so Likely	20	11.2	11.6	93.6
	Not at all Likely	11	6.1	6.4	100.0
	Total	173	96.6	100.0	
Missing	System	6	3.4		
Total		179	100.0		

Table 58. First Questionnaire Results - University App Feature Usage Likeliness - Lifestyle Guidance

Entertainment & Social Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Likely	80	44.7	46.2	46.2
	Likely	53	29.6	30.6	76.9
	Neutral	20	11.2	11.6	88.4
	Not so Likely	11	6.1	6.4	94.8
	Not at all Likely	9	5.0	5.2	100.0
	Total	173	96.6	100.0	
Missing	System	6	3.4		
Total		179	100.0		

Table 59. First Questionnaire Results - University App Feature Usage Likeliness - Entertainment & Social

Offers & Deals Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Likely	80	44.7	46.2	46.2
	Likely	50	27.9	28.9	75.1
	Neutral	27	15.1	15.6	90.8
	Not so Likely	7	3.9	4.0	94.8
	Not at all Likely	9	5.0	5.2	100.0
	Total	173	96.6	100.0	
Missing	System	6	3.4		
Total		179	100.0		

Table 60. First Questionnaire Results - University App Feature Usage Likeliness - Offers & Deals

Facilities Guidance & Info					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Likely	63	35.2	36.2	36.2
	Likely	59	33.0	33.9	70.1
	Neutral	30	16.8	17.2	87.4
	Not so Likely	12	6.7	6.9	94.3
	Not at all Likely	10	5.6	5.7	100.0
	Total	174	97.2	100.0	
Missing	System	5	2.8		
Total		179	100.0		

Table 61. First Questionnaire Results - University App Feature Usage Likeliness - Facilities Guidance

Campus Directions					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Likely	86	48.0	49.1	49.1
	Likely	45	25.1	25.7	74.9
	Neutral	22	12.3	12.6	87.4
	Not so Likely	11	6.1	6.3	93.7
	Not at all Likely	11	6.1	6.3	100.0
	Total	175	97.8	100.0	
Missing	System	4	2.2		
Total		179	100.0		

Table 62. First Questionnaire Results - University App Feature Usage Likeliness - Campus Directions

A.3.2. Relationship and Correlation Detection

Test Null hypothesis: There is no relationship between study discipline and the amount of smartphones : **TRUE**

Association: Chi Square, Phi and Cramer's V; Strength: Spearman rho, Kendall tau

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app) * In which discipline are you studying?	179	100.0%	0	.0%	179	100.0%

Symmetric Measures

		Value	Asymp. Std. Error^a	Approx. T^b	Approx. Sig.
Nominal by Nominal	Phi	.137			.764
	Cramer's V	.137			.764
Interval by Interval	Pearson's R	.015	.075	.195	.846^c
Ordinal by Ordinal	Spearman Correlation	.016	.076	.210	.834^c
N of Valid Cases		179			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Based on normal approximation.

Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app) * In which discipline are you studying? Crosstabulation

Count

		In which discipline are you studying?							
		a.Business	b.Arts, Humanities & Social Science	c.Education	d.Health Sciences	e.Engineering	f.Science	g.Other [please specify]	Total
Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app)	yes	20	27	17	15	27	24	7	137
	no	6	10	2	4	9	10	1	42
Total		26	37	19	19	36	34	8	179

Table 63. First Questionnaire Results - Smartphone Ownership Vs Study Discipline Correlation – Pt 1

Correlations

			Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app)	In which discipline are you studying?
Kendall's tau_b	Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app)	Correlation Coefficient	1.000	.014
		Sig. (2-tailed)	.	.833
		N	179	179
	In which discipline are you studying?	Correlation Coefficient	.014	1.000
		Sig. (2-tailed)	.833	.
		N	179	179
Spearman's rho	Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app)	Correlation Coefficient	1.000	.016
		Sig. (2-tailed)	.	.834
		N	179	179
	In which discipline are you studying?	Correlation Coefficient	.016	1.000
		Sig. (2-tailed)	.834	.
		N	179	179

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.349[a]	6	.764
Likelihood Ratio	3.719	6	.715
Linear-by-Linear Association	.038	1	.845
N of Valid Cases	179		

a. 3 cells (21.4%) have expected count less than 5. The minimum expected count is 1.88.

Table 64. First Questionnaire Results - Smartphone Ownership Vs Study Discipline Correlation – Pt 2

A.4. The Second Questionnaire

Please answer the following questions.

1. Do you use a smartphone? (A smartphone is defined as a mobile phone that can access the internet to download and install an app)
    a. Yes
    b. No

2. If you use a smartphone, what is its manufacturer brand?
    a. Apple
    b. HTC
    c. Samsung
    d. Blackberry
    e. Nokia
    f. LG
    g. Sony Ericsson
    h. Other [please specify]
    i. Don't Know

3. If you use a smartphone, what operating system does it run?
    a. Apple OS
    b. Android
    c. Windows Phone
    d. Blackberry
    e. Symbian
    f. Other [please specify]
    g. Don't Know

4. If you use an Android smartphone, what version of Android does it run?
    a. Android 2.1 or earlier
    b. Froyo, Android 2.2
    c. Gingerbread, Android 2.3
    d. Ice Cream Sandwich, Android 4.0
    e. Jelly Bean, Android 4.1/4.2
    f. Other [please specify]
    g. Don't know

5. If you use an Apple iPhone, what version of the operating system does it run?
    a. Version 3.x
    b. Version 4.x
    c. Version 5.x
    d. Version 6.x

e. Don't know
f. Other [please specify]

6. If you use a Windows Phone, what version of the operating system does it run?
   a. Version 7 or earlier
   b. Version 7.5
   c. Version 7.8
   d. Version 8
   e. Don't Know
   f. Other [please specify]

7. If you use a smartphone, what type of mobile operator plan do you have with your smartphone?
   a. Pre-pay
   b. Post-pay
   c. Don't know

8. If you use a smartphone, please indicate how important the following features are to you:

	Very Important	Important	Neutral	Not so Important	Not at all Important
Accessing Social Networks					
Using Apps to Access Info					
Performing Web Searches					
Gaming					
Watching Videos					
Listening to Audio/Radio					
Taking Photos					
Map Navigation & Directions					
Downloading & Installing Apps					
Web Browsing					

9. If you use a smartphone, when did you get it?
    a. In the last 6 months
    b. In the last 12 months
    c. Over a year ago
    d. Don't Know

10. If you DO NOT use a smartphone, do you intend to get a smartphone in the next year?
    a. Yes
    b. No
    c. Don't know

11. If you INTEND ON getting a smartphone, why is this your intention?

12. If you DO INTEND in getting a smartphone, please indicate how important the following features are to you:

	Very Important	Important	Neutral	Not so Important	Not at all Important
Accessing Social Networks					
Using Apps to Access Info					
Performing Web Searches					
Gaming					
Watching Videos					
Listening to Audio/Radio					
Taking Photos					
Map Navigation & Directions					
Downloading & Installing Apps					
Web Browsing					

13. If you DO NOT INTEND on getting a smartphone, why is this?

14. Please indicate how often you use the following sources to access information about the University?

(Please tick all that apply)

	Never	Monthly	Several times per week	Once per day	Several times per day
University Website					
Notice Boards					
Social Networks					
Contact with Student Union					
First 7 weeks programme – online					
First 7 weeks programme – offline					
First 7 weeks programme – android app & mobile website					
Word of Mouth					

15. For the following types of University information, please indicate how important each one is to you during your first year of college:

	Not at all Important	Not so Important	Neutral	Important	Very Important
Campus Directions					
Facilities Guidance & Info					
Offers & Deals Info					
Entertainment & Social Info					
Lifestyle Guidance & Info					
Academic Guidance & Info					
Career Guidance & Info					
Skills Guidance & Info					

16. Were you aware of the First 7 Weeks Android app & mobile website (first7weeks.ul.ie) launched this year?
    a. Yes
    b. No

17. How often do you scan any of the First 7 Weeks QR codes on campus?

	Never	Monthly	Several times per week	Once per day	Several times per day
Scan QR with smartphone (not within F7W app)					
Scan QR within F7W app to view location on floor map					

18. Please indicate how often you use the following features of the First 7 Weeks app & mobile website (Please tick all that apply)

	Several times per day	Once per day	Several times per week	Monthly	Never
Information on Weekly Theme					
Weekly Photos & Videos					
Weekly Documents					
Main Building Floor Maps					
Other Building Floor Maps					
F7W Facebook page					

19. Please indicate how much you agree with the following statement:

	Strongly Disagree	Disgree	Neither agree or disagree	Agree	Strongly Agree
I enjoyed using the					

mapping features in the First Seven Weeks Android app to explore and find my way around each building					
Using the First Seven Weeks app has had a positive effect on my experience of starting college at UL					

20. For the following mapping features in the First Seven Weeks Android app, please indicate how useful each one is to you:

	Very useful	Useful	Neutral	Not so useful	Not at all useful	Did not use
Scan a QR code to view your location on a floor map						
Find rooms in a building from the list of rooms						
Explore where rooms are located by tapping points on a floor map						
Plot a route to a room on a particular floor						
Learn your way around using the floor maps						
Checking the map without being in the building						

21. Please enter any comments you may have about the First 7 Weeks Android app and mobile website.

22. If you are open to answering further questions about the First 7 Weeks app and mobile website at a later date, please enter your email address. (This is collected confidentially and is not linked to any of the answers submitted in this survey)

23. What type of student are you?
    c. Undergraduate
    d. Postgraduate

24. In which year are you studying?
    f. 1st year
    g. 2nd year
    h. 3rd year
    i. 4th year
    j. Other [please specify]

25. Are you 18 years of age or over?
    c. Yes
    d. No

26. In which discipline are you studying?
    i. Business
    j. Arts, Humanities & Social Science
    k. Education
    l. Health Sciences
    m. Engineering
    n. Science
    o. Other [please specify]
    p. Don't Know

27. Please enter any comments that you have about this survey.

A.5. Research Ethics Information and Consent Sheet

EMAIL QUESTIONNAIRE INFORMATION & CONSENT SHEET

EAGNA CHUN GNÍMH

Are you a first year student studying at the University of Limerick?

If so, I would like to invite you to complete this short questionnaire about smartphone usage among first year students. I am an MSc student conducting research in this area.

This short questionnaire will take roughly 5 minutes and is completely anonymous.

By clicking on the questionnaire link below you consent to participate in this research project, however you are free to withdraw from the questionnaire at any time.

LINK TO ONLINE QUESTIONNAIRE TO BE ENTERED HERE

Questions or concerns regarding this research project can be sent to the primary investigator and researcher Daryl Feehely (daryl.feehely@ul.ie), to the research project supervisor Mikael Fernström (mikael.fernstrom@ul.ie), to the Centre for Teaching & Learning (maura.murphy@ul.ie) or to the Science & Engineering Research Ethics Committee Chairperson (SciEngEthics@ul.ie).

A.6. The Second Questionnaire Results

A.6.1.Results Data

StudyYear

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1st Year	196	96.1	96.1	96.1
	2nd Year	2	1.0	1.0	97.1
	3rd Year	1	.5	.5	97.5
	Postgrad	3	1.5	1.5	99.0
	Study Abroad	2	1.0	1.0	100.0
	Total	204	100.0	100.0	

Table 65. Second Questionnaire Results - Study Year

StudyDiscipline

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Business	19	9.7	9.7	9.7
	Arts, Humanities & Social Sciences	57	29.1	29.1	38.8
	Education	15	7.7	7.7	46.4
	Health Science	18	9.2	9.2	55.6
	Engineering	36	18.4	18.4	74.0
	Science	51	26.0	26.0	100.0
	Total	196	100.0	100.0	

Table 66. Second Questionnaire Results - Study Discipline

UseSmartphone					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	159	81.1	81.1	81.1
	No	37	18.9	18.9	100.0
	Total	196	100.0	100.0	

Table 67. Second Questionnaire Results - Smartphone Ownership

GetSmartphoneWhen					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	1	.6	.6	.6
	In the last 6 months	60	37.7	37.7	38.4
	In the last 12 months	28	17.6	17.6	56.0
	Over a year ago	70	44.0	44.0	100.0
	Total	159	100.0	100.0	

Table 68. Second Questionnaire Results - Smartphone Ownership Periods

Manufacturer					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	4	2.5	2.5	2.5
	Apple	42	26.4	26.4	28.9
	HTC	25	15.7	15.7	44.7
	Samsung	50	31.4	31.4	76.1
	Blackberry	4	2.5	2.5	78.6
	Nokia	16	10.1	10.1	88.7
	LG	1	.6	.6	89.3
	Sony Ericsson	15	9.4	9.4	98.7
	Alcetel	1	.6	.6	99.4
	Huawei	1	.6	.6	100.0
	Total	159	100.0	100.0	

Table 69. Second Questionnaire Results - Smartphone Manufacturer

OS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	5	3.1	3.1	3.1
	Apple iOS	42	26.4	26.4	29.6
	Android	93	58.5	58.5	88.1
	Windows Phone	14	8.8	8.8	96.9
	Blackberry	5	3.1	3.1	100.0
	Total	159	100.0	100.0	

Table 70. Second Questionnaire Results - Smartphone Operating Systems

AndroidVersion

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	38	23.9	40.9	40.9
	Android 2.1 or earlier	13	8.2	14.0	54.8
	Froyo, Android 2.2	3	1.9	3.2	58.1
	Gingerbread, Android 2.3	12	7.5	12.9	71.0
	Ice Cream Sandwich, Android 4.0	13	8.2	14.0	84.9
	Jelly Bean, Android 4.1/4.2	14	8.8	15.1	100.0
	Total	93	58.5	100.0	
Missing	System	66	41.5		
Total		159	100.0		

Table 71. Second Questionnaire Results - Android OS Versions

iOSVersion					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	6	3.8	14.3	14.3
	Version 3.X	3	1.9	7.1	21.4
	Version 4.X	3	1.9	7.1	28.6
	Version 5.X	2	1.3	4.8	33.3
	Version 6.X	28	17.6	66.7	100.0
	Total	42	26.4	100.0	
Missing	System	117	73.6		
Total		159	100.0		

Table 72. Second Questionnaire Results - iOS OS Versions

WinPhoneVersion					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	1	.6	7.1	7.1
	Version 7 or lower	1	.6	7.1	14.3
	Version 7.5	5	3.1	35.7	50.0
	Version 8	7	4.4	50.0	100.0
	Total	14	8.8	100.0	
Missing	System	145	91.2		
Total		159	100.0		

Table 73. Second Questionnaire Results - Windows Phone OS Versions

OperatorPlan					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	2	1.3	1.3	1.3
	None	4	2.5	2.5	3.8
	Pre-pay	113	71.1	71.1	74.8
	Post-pay	40	25.2	25.2	100.0
	Total	159	100.0	100.0	

Table 74. Second Questionnaire Results - Operator Plan

ImportanceSocialNetworks					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	60	37.7	37.7	37.7
	Important	62	39.0	39.0	76.7
	Neutral	15	9.4	9.4	86.2
	Not so important	13	8.2	8.2	94.3
	Not at all important	9	5.7	5.7	100.0
	Total	159	100.0	100.0	

Table 75. Second Questionnaire Results - Feature Importance - Social Networks

ImportanceInfoApps					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	50	31.4	31.4	31.4
	Important	76	47.8	47.8	79.2
	Neutral	24	15.1	15.1	94.3
	Not so important	6	3.8	3.8	98.1
	Not at all important	3	1.9	1.9	100.0
	Total	159	100.0	100.0	

Table 76. Second Questionnaire Results - Feature Importance - Using Apps to Access Info

ImportanceWebSearches					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	84	52.8	52.8	52.8
	Important	56	35.2	35.2	88.1
	Neutral	10	6.3	6.3	94.3
	Not so important	6	3.8	3.8	98.1
	Not at all important	3	1.9	1.9	100.0
	Total	159	100.0	100.0	

Table 77. Second Questionnaire Results - Feature Importance - Performing Web Searches

ImportanceGaming					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	11	6.9	6.9	6.9
	Important	41	25.8	25.8	32.7
	Neutral	41	25.8	25.8	58.5
	Not so important	40	25.2	25.2	83.6
	Not at all important	26	16.4	16.4	100.0
	Total	159	100.0	100.0	

Table 78. Second Questionnaire Results - Feature Importance - Gaming

ImportanceVideo					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	27	17.0	17.0	17.0
	Important	52	32.7	32.7	49.7
	Neutral	40	25.2	25.2	74.8
	Not so important	28	17.6	17.6	92.5
	Not at all important	12	7.5	7.5	100.0
	Total	159	100.0	100.0	

Table 79. Second Questionnaire Results - Feature Importance - Watching Videos

ImportanceAudioRadio					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	50	31.4	31.4	31.4
	Important	46	28.9	28.9	60.4
	Neutral	31	19.5	19.5	79.9
	Not so important	22	13.8	13.8	93.7
	Not at all important	10	6.3	6.3	100.0
	Total	159	100.0	100.0	

Table 80. Second Questionnaire Results - Feature Importance - Listening to Audio/Radio

ImportancePhoto					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	53	33.3	33.3	33.3
	Important	62	39.0	39.0	72.3
	Neutral	28	17.6	17.6	89.9
	Not so important	10	6.3	6.3	96.2
	Not at all important	6	3.8	3.8	100.0
	Total	159	100.0	100.0	

Table 81. Second Questionnaire Results - Feature Importance - Taking Photos

ImportanceMapDirections					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	31	19.5	19.5	19.5
	Important	52	32.7	32.7	52.2
	Neutral	39	24.5	24.5	76.7
	Not so important	29	18.2	18.2	95.0
	Not at all important	8	5.0	5.0	100.0
	Total	159	100.0	100.0	

Table 82. Second Questionnaire Results - Feature Importance - Navigation Maps & Directions

ImportanceDownloadApps					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	48	30.2	30.2	30.2
	Important	70	44.0	44.0	74.2
	Neutral	28	17.6	17.6	91.8
	Not so important	10	6.3	6.3	98.1
	Not at all important	3	1.9	1.9	100.0
	Total	159	100.0	100.0	

Table 83. Second Questionnaire Results - Feature Importance - Downloading Apps

ImportanceWebBrowsing		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	84	52.8	52.8	52.8
	Important	46	28.9	28.9	81.8
	Neutral	21	13.2	13.2	95.0
	Not so important	6	3.8	3.8	98.7
	Not at all important	2	1.3	1.3	100.0
	Total	159	100.0	100.0	

Table 84. Second Questionnaire Results - Feature Importance - Web Browsing

IntendGettingPhone		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Don't Know	10	5.1	27.0	27.0
	Yes	7	3.6	18.9	45.9
	No	20	10.2	54.1	100.0
	Total	37	18.9	100.0	
Missing	System	159	81.1		
Total		196	100.0		

Table 85. Second Questionnaire Results - No Smartphone: Intention on Getting a Smartphone

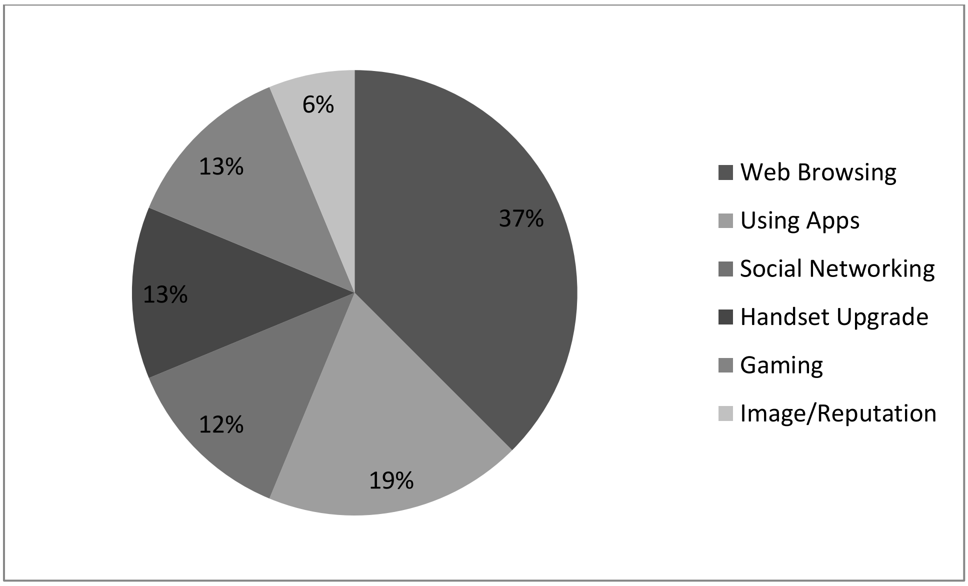


Figure 68. Second Questionnaire Results - Intention on Getting a Smartphone - Reasons

Quotes on Intention to Get a Smartphone

"internet..games.apps and etc "

"I need a new phone as my own doesn't work as well as it used to since it is over 4 years old and I like the phone i have chosen to get."

"Internet usage on the go"

"You can use the internet and they look better."

"Easier access to internet. My own phone is fecked. Just heard they're good and said i'd give it a go. "

"Getting up to date"

"you can do more with a smart phone then a normal one."

"It would be easier to keep up to date with social netwooking, tweets etc and would use the"

Figure 69. Second Questionnaire Results - Intention on Getting a Smartphone Reasons – Quotes

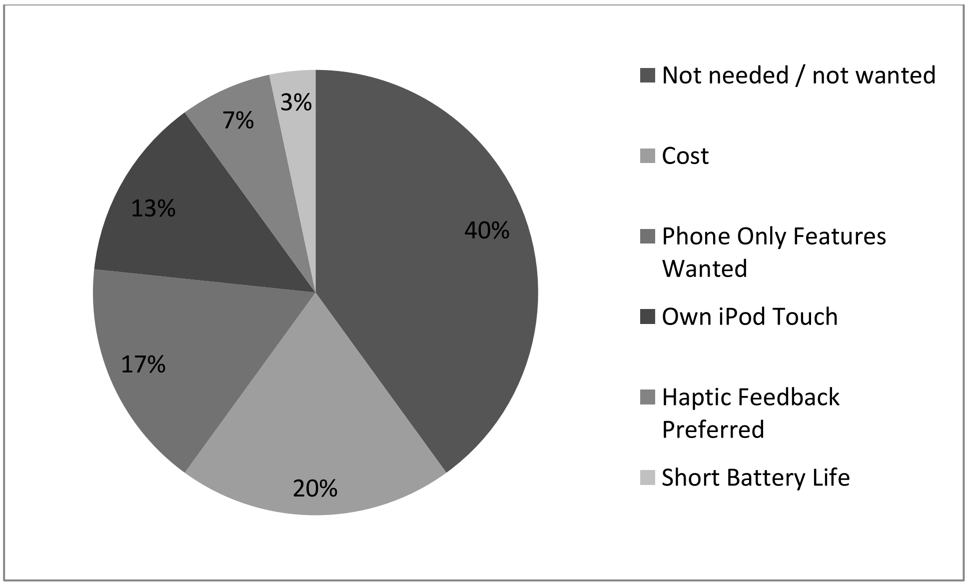


Figure 70. Second Questionnaire Results - No Intention on Getting a Smartphone – Reasons

Quotes on No Intention to Get a Smartphone

"Too expensive!"

"I prefer having a button phone."

"I prefer having my phone for texting and calling people (I have an ipod touch which i use for the internet and apps etc)"

"dont need one"

"I don't need one"

"I am more partial to computers than phones."

"Poor battery life. I don't object to more features, apps for example, but I draw the line when they interfere with a phone's primary purpose - to make and receive calls/texts."

"My old phone still works without many problems as it has for the last five years. It is not necessary to buy a new phone."

"i am happy with the phone i have. smartphones are generally expensive. also afraid i would break it"

"To costly"

"I think that a phone should be for texting and calling, after that laptops are sufficient"

"Don't need internet all the time. Having a laptop fulfills this requirement."

"Because the phone I have works fine, and I don't really need a smart phone"

"What is a smart phone? I'm 45 years old and not into technology and only use the technology I need to."

"because i have an ipod touch and it does everything a smartphone does, so i just get a cheap phone"

"cause im not that bothered, and if i lose my phone i wont care but if i lost a good phone id be upset! ha"

"No need.."

"I have an ipod touch with apps and dont need a smartphone"

"don't need one"

"Cannot afford it"

"The phone I have works away grand, no need for one"

"Happy with phone I have"

"I prefer buttons just for clarity when ringing or texting people. I also have no need for a smartphone since i have an ipod touch which i use for the internet."

Figure 71. Second Questionnaire Results - No Intention on Getting a Smartphone - Reason Quotes

NoPhoneImportanceWebBrowsing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	4	10.8	57.1	57.1
	Important	3	8.1	42.9	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 86. Second Questionnaire Results - No Smartphone Feature Importance - Web Browsing

NoPhoneImportanceDownloadingApps					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	2	5.4	28.6	28.6
	Important	3	8.1	42.9	71.4
	Neutral	1	2.7	14.3	85.7
	Not so important	1	2.7	14.3	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 87. Second Questionnaire Results - No Smartphone Feature Importance - Downloading Apps

NoPhoneImportanceAppsInfo					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	2	5.4	28.6	28.6
	Important	4	10.8	57.1	85.7
	Neutral	1	2.7	14.3	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 88. Second Questionnaire Results - No Smartphone Feature Importance - Accessing Apps for Info

NoPhoneImportanceMapDirections					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	1	2.7	14.3	14.3
	Important	3	8.1	42.9	57.1
	Neutral	3	8.1	42.9	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 89. Second Questionnaire Results - No Smartphone Feature Importance - Map Navigaiton & Directions

NoPhoneImportancePhotos					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	3	8.1	42.9	42.9
	Important	4	10.8	57.1	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 90. Second Questionnaire Results - No Smartphone Feature Importance - Taking Photos

NoPhoneImportanceAudioRadio					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	3	8.1	42.9	42.9
	Important	3	8.1	42.9	85.7
	Neutral	1	2.7	14.3	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 91. Second Questionnaire Results - No Smartphone Feature Importance - Listenting to Audio/Radio

NoPhoneImportanceVideos					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	3	8.1	42.9	42.9
	Important	2	5.4	28.6	71.4
	Neutral	1	2.7	14.3	85.7
	Not so important	1	2.7	14.3	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 92. Second Questionnaire Results - No Smartphone Feature Importance - Watching Videos

NoPhoneImportanceGaming		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	1	2.7	14.3	14.3
	Important	2	5.4	28.6	42.9
	Neutral	2	5.4	28.6	71.4
	Not at all important	2	5.4	28.6	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 93. Second Questionnaire Results - No Smartphone Feature Importance – Gaming

NoPhoneImportanceWebSearches		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	4	10.8	57.1	57.1
	Important	3	8.1	42.9	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 94. Second Questionnaire Results - No Smartphone Feature Importance - Performing Web Searches

NoPhoneImportanceSocialNetworks		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	3	8.1	42.9	42.9
	Important	3	8.1	42.9	85.7
	Neutral	1	2.7	14.3	100.0
	Total	7	18.9	100.0	
Missing	System	30	81.1		
Total		37	100.0		

Table 95. Second Questionnaire Results - No Smartphone Feature Importance - Accessing Social Networks

InfoWordOfMouth		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	32	16.3	16.3	16.3
	Once per day	31	15.8	15.8	32.1
	Several times per week	67	34.2	34.2	66.3
	Monthly	30	15.3	15.3	81.6
	Never	36	18.4	18.4	100.0
	Total	196	100.0	100.0	

Table 96. Second Questionnaire Results - University Information Sources Usage – Word Of Mouth

InfoF7WApp		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	3	1.5	1.5	1.5
	Once per day	3	1.5	1.5	3.1
	Several times per week	2	1.0	1.0	4.1
	Monthly	16	8.2	8.2	12.2
	Never	172	87.8	87.8	100.0
	Total	196	100.0	100.0	

Table 97. Second Questionnaire Results - University Information Sources Usage - F7W App

InfoF7WOffline		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	1	.5	.5	.5
	Several times per week	9	4.6	4.6	5.1
	Monthly	22	11.2	11.2	16.3
	Never	164	83.7	83.7	100.0
	Total	196	100.0	100.0	

Table 98. Second Questionnaire Results - University Information Sources Usage - F7W Offline

InfoF7WOnline

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	2	1.0	1.0	1.0
	Once per day	2	1.0	1.0	2.0
	Several times per week	11	5.6	5.6	7.7
	Monthly	33	16.8	16.8	24.5
	Never	148	75.5	75.5	100.0
	Total	196	100.0	100.0	

Table 99. Second Questionnaire Results - University Information Sources Usage - F7W Online

InfoStudentUnion

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	1	.5	.5	.5
	Once per day	6	3.1	3.1	3.6
	Several times per week	12	6.1	6.1	9.7
	Monthly	59	30.1	30.1	39.8
	Never	118	60.2	60.2	100.0
	Total	196	100.0	100.0	

Table 100. Second Questionnaire Results - University Information Sources Usage - Student's Union

InfoSocialNetworks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	57	29.1	29.1	29.1
	Once per day	45	23.0	23.0	52.0
	Several times per week	56	28.6	28.6	80.6
	Monthly	20	10.2	10.2	90.8
	Never	18	9.2	9.2	100.0
	Total	196	100.0	100.0	

Table 101. Second Questionnaire Results - University Information Sources Usage - Social Networks

InfoNoticeBoardOffline					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	3	1.5	1.5	1.5
	Once per day	5	2.6	2.6	4.1
	Several times per week	17	8.7	8.7	12.8
	Monthly	42	21.4	21.4	34.2
	Never	129	65.8	65.8	100.0
	Total	196	100.0	100.0	

Table 102. Second Questionnaire Results - University Information Sources Usage - Offline Noticeboards

InfoNoticeBoardOnline					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	7	3.6	3.6	3.6
	Once per day	8	4.1	4.1	7.7
	Several times per week	27	13.8	13.8	21.4
	Monthly	47	24.0	24.0	45.4
	Never	107	54.6	54.6	100.0
	Total	196	100.0	100.0	

Table 103. Second Questionnaire Results - University Information Sources Usage - Online Noticeboards

InfoUniWebsite					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	29	14.8	14.9	14.9
	Once per day	15	7.7	7.7	22.7
	Several times per week	74	37.8	38.1	60.8
	Monthly	62	31.6	32.0	92.8
	Never	14	7.1	7.2	100.0
	Total	194	99.0	100.0	
Missing	System	2	1.0		
Total		196	100.0		

Table 104. Second Questionnaire Results - University Information Sources Usage - University Website

ImportanceSkills					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	43	21.9	21.9	21.9
	Important	63	32.1	32.1	54.1
	Neutral	61	31.1	31.1	85.2
	Not so important	21	10.7	10.7	95.9
	Not at all important	8	4.1	4.1	100.0
	Total	196	100.0	100.0	

Table 105. Second Questionnaire Results - University Information Importance – Skills Guidance

ImportanceCareer					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	48	24.5	24.5	24.5
	Important	50	25.5	25.5	50.0
	Neutral	62	31.6	31.6	81.6
	Not so important	27	13.8	13.8	95.4
	Not at all important	9	4.6	4.6	100.0
	Total	196	100.0	100.0	

Table 106. Second Questionnaire Results - University Information Importance - Career Guidance

ImportanceAcademic					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	66	33.7	33.7	33.7
	Important	81	41.3	41.3	75.0
	Neutral	35	17.9	17.9	92.9
	Not so important	12	6.1	6.1	99.0
	Not at all important	2	1.0	1.0	100.0
	Total	196	100.0	100.0	

Table 107. Second Questionnaire Results - University Information Importance - Academic Guidance

ImportantLifestyle					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	19	9.7	9.7	9.7
	Important	77	39.3	39.3	49.0
	Neutral	56	28.6	28.6	77.6
	Not so important	33	16.8	16.8	94.4
	Not at all important	11	5.6	5.6	100.0
	Total	196	100.0	100.0	

Table 108. Second Questionnaire Results - University Information Importance - Lifestyle Guidance

InportantEnts					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	33	16.8	16.8	16.8
	Important	95	48.5	48.5	65.3
	Neutral	39	19.9	19.9	85.2
	Not so important	21	10.7	10.7	95.9
	Not at all important	8	4.1	4.1	100.0
	Total	196	100.0	100.0	

Table 109. Second Questionnaire Results - University Information Importance - Entertainment & Social

InportanceOffers					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	41	20.9	20.9	20.9
	Important	70	35.7	35.7	56.6
	Neutral	53	27.0	27.0	83.7
	Not so important	19	9.7	9.7	93.4
	Not at all important	13	6.6	6.6	100.0
	Total	196	100.0	100.0	

Table 110. Second Questionnaire Results - University Information Importance - Deals & Offers

ImportanceFacilities					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	49	25.0	25.0	25.0
	Important	92	46.9	46.9	71.9
	Neutral	33	16.8	16.8	88.8
	Not so important	15	7.7	7.7	96.4
	Not at all important	7	3.6	3.6	100.0
	Total	196	100.0	100.0	

Table 111. Second Questionnaire Results - University Information Importance - Facilities Guidance

ImportantDirections					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Important	76	38.8	38.8	38.8
	Important	74	37.8	37.8	76.5
	Neutral	21	10.7	10.7	87.2
	Not so important	13	6.6	6.6	93.9
	Not at all important	12	6.1	6.1	100.0
	Total	196	100.0	100.0	

Table 112. Second Questionnaire Results - University Information Importance - Campus Directions

AwareF7WApp					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	101	51.5	53.7	53.7
	No	87	44.4	46.3	100.0
	Total	188	95.9	100.0	
Missing	System	8	4.1		
Total		196	100.0		

Table 113. Second Questionnaire Results - Awareness of First Seven Weeks Android App

F7WAppScanOutside					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	3	1.5	1.5	1.5
	Several times per week	4	2.0	2.0	3.6
	Monthly	12	6.1	6.1	9.7
	Never	177	90.3	90.3	100.0
	Total	196	100.0	100.0	

Table 114. Second Questionnaire Results - F7W App Feature Usage - QR Scan Outside App

F7WAppScanInside					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	1	.5	.5	.5
	Several times per week	3	1.5	1.5	2.0
	Monthly	11	5.6	5.6	7.7
	Never	181	92.3	92.3	100.0
	Total	196	100.0	100.0	

Table 115. Second Questionnaire Results - F7W App Feature Usage - QR Scan Within App

F7WWeeklyInfo					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	11	5.6	5.6	5.6
	Once per day	5	2.6	2.6	8.2
	Several times per week	12	6.1	6.1	14.3
	Monthly	13	6.6	6.6	20.9
	Never	155	79.1	79.1	100.0
	Total	196	100.0	100.0	

Table 116. Second Questionnaire Results - F7W App Feature Usage - Weekly Info

F7WWeeklyPhotoVideo					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	9	4.6	4.6	4.6
	Once per day	3	1.5	1.5	6.1
	Several times per week	15	7.7	7.7	13.8
	Monthly	11	5.6	5.6	19.4
	Never	158	80.6	80.6	100.0
	Total	196	100.0	100.0	

Table 117. Second Questionnaire Results - F7W App Feature Usage - Weekly Photos & Video

F7WWeeklyDocs					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	11	5.6	5.6	5.6
	Once per day	4	2.0	2.0	7.7
	Several times per week	8	4.1	4.1	11.7
	Monthly	12	6.1	6.1	17.9
	Never	161	82.1	82.1	100.0
	Total	196	100.0	100.0	

Table 118. Second Questionnaire Results - F7W App Feature Usage - Weekly Documents

F7WMapsMainBldg					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	16	8.2	8.2	8.2
	Once per day	8	4.1	4.1	12.2
	Several times per week	8	4.1	4.1	16.3
	Monthly	15	7.7	7.7	24.0
	Never	149	76.0	76.0	100.0
	Total	196	100.0	100.0	

Table 119. Second Questionnaire Results - F7W App Feature Usage - Maps - Main Building

F7WMapsOtherBldg		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	17	8.7	8.7	8.7
	Once per day	5	2.6	2.6	11.2
	Several times per week	7	3.6	3.6	14.8
	Monthly	16	8.2	8.2	23.0
	Never	151	77.0	77.0	100.0
	Total	196	100.0	100.0	

Table 120. Second Questionnaire Results - F7W App Feature Usage - Maps - Other Buildings

F7WFacebook		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Several times per day	12	6.1	6.1	6.1
	Once per day	7	3.6	3.6	9.7
	Several times per week	10	5.1	5.1	14.8
	Monthly	23	11.7	11.7	26.5
	Never	144	73.5	73.5	100.0
	Total	196	100.0	100.0	

Table 121. Second Questionnaire Results - F7W App Feature Usage - F7W Facebook Page

F7WEnjoyed		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	5	2.6	2.6	2.6
	Agree	14	7.1	7.1	9.7
	Neither agree or disagree	144	73.5	73.5	83.2
	Disagree	6	3.1	3.1	86.2
	Strongly Disagree	27	13.8	13.8	100.0
	Total	196	100.0	100.0	

Table 122. Second Questionnaire Results - Enjoyment of Using F7W App to Explore

F7WPositiveEffect					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	7	3.6	3.6	3.6
	Agree	18	9.2	9.2	12.8
	Neither agree or disagree	143	73.0	73.0	85.7
	Disagree	4	2.0	2.0	87.8
	Strongly Disagree	24	12.2	12.2	100.0
	Total	196	100.0	100.0	

Table 123. Second Questionnaire Results - Positive Effect of F7W App on Starting College in UL

F7WUsefulScanViewLocation					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Useful	12	6.1	6.1	6.1
	Useful	19	9.7	9.7	15.8
	Neutral	55	28.1	28.1	43.9
	Not so useful	3	1.5	1.5	45.4
	Not at all useful	1	.5	.5	45.9
	Did not use	106	54.1	54.1	100.0
	Total	196	100.0	100.0	

Table 124. Second Questionnaire Results - F7W App Feature Usefulness - Scan QR to View Location

F7WUsefulRoomList					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Useful	18	9.2	9.2	9.2
	Useful	26	13.3	13.3	22.4
	Neutral	48	24.5	24.5	46.9
	Not so useful	3	1.5	1.5	48.5
	Did not use	101	51.5	51.5	100.0
	Total	196	100.0	100.0	

Table 125. Second Questionnaire Results - F7W App Feature Usefulness - Room List

F7WUsefulTapExploreRooms					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Useful	12	6.1	6.1	6.1
	Useful	24	12.2	12.2	18.4
	Neutral	54	27.6	27.6	45.9
	Not so useful	3	1.5	1.5	47.4
	Did not use	103	52.6	52.6	100.0
	Total	196	100.0	100.0	

Table 126. Second Questionnaire Results - F7W App Feature Usefulness - Tap & Explore Nodes & Rooms

F7WUsefulMapRoute					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Useful	10	5.1	5.1	5.1
	Useful	25	12.8	12.8	17.9
	Neutral	53	27.0	27.0	44.9
	Not so useful	2	1.0	1.0	45.9
	Not at all useful	1	.5	.5	46.4
	Did not use	105	53.6	53.6	100.0
	Total	196	100.0	100.0	

Table 127. Second Questionnaire Results - F7W App Feature Usefulness - Plotting Routes on Floormap

F7WUsefulLearn					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Useful	12	6.1	6.1	6.1
	Useful	28	14.3	14.3	20.4
	Neutral	52	26.5	26.5	46.9
	Not so useful	4	2.0	2.0	49.0
	Not at all useful	1	.5	.5	49.5
	Did not use	99	50.5	50.5	100.0
	Total	196	100.0	100.0	

Table 128. Second Questionnaire Results - F7W App Feature Usefulness - Using App to Learn Environment

F7WUsefulCheckMapNotInBldg					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Useful	14	7.1	7.1	7.1
	Useful	30	15.3	15.3	22.4
	Neutral	48	24.5	24.5	46.9
	Not so useful	1	.5	.5	47.4
	Not at all useful	1	.5	.5	48.0
	Did not use	102	52.0	52.0	100.0
	Total	196	100.0	100.0	

Table 129. Second Questionnaire Results - F7W App Feature Usefulness - Check Map While Not In Building

A.6.2. Relationship and Correlation Detection

Test Null hypothesis: There is no relationship between study discipline and the amount of smartphones : **TRUE**

Association: Chi Square, Phi and Cramer's V; Strength: Spearman rho, Kendall tau

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
UseSmartphone * StudyDiscipline	196	100.0%	0	0.0%	196	100.0%

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.104			.833
	Cramer's V	.104			.833
Interval by Interval	Pearson's R	-.014	.068	-.195	.846[c]
Ordinal by Ordinal	Spearman Correlation	-.012	.067	-.165	.869[c]
N of Valid Cases		196			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on normal approximation.

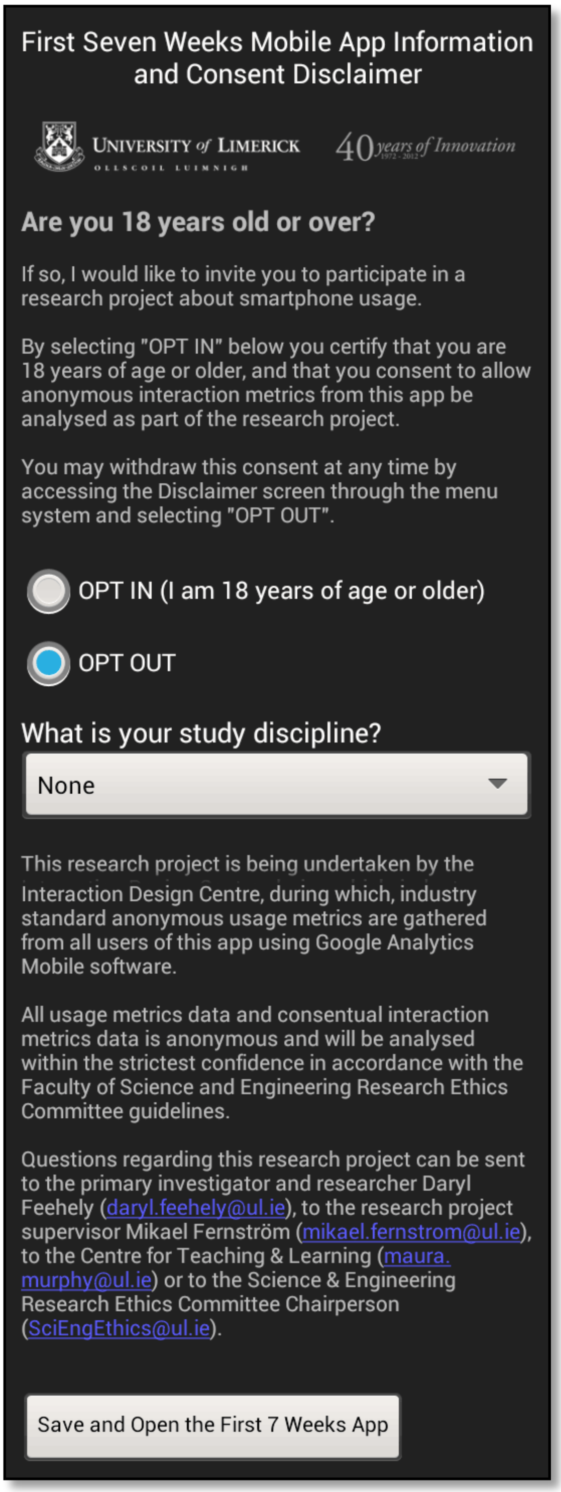
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	2.114[a]	5	.833
Likelihood Ratio	2.198	5	.821
Linear-by-Linear Association	.038	1	.845
N of Valid Cases	196		

a. 3 cells (25.0%) have expected count less than 5. The minimum expected count is 2.83.

Table 130. First Questionnaire Results - Smartphone Ownership Vs Study Discipline Correlation

Appendix B – Android Application Consent Form



First Seven Weeks Mobile App Information and Consent Disclaimer

UNIVERSITY of LIMERICK
OLLSCOIL LUIMNIGH

40 years of Innovation

Are you 18 years old or over?

If so, I would like to invite you to participate in a research project about smartphone usage.

By selecting "OPT IN" below you certify that you are 18 years of age or older, and that you consent to allow anonymous interaction metrics from this app be analysed as part of the research project.

You may withdraw this consent at any time by accessing the Disclaimer screen through the menu system and selecting "OPT OUT".

OPT IN (I am 18 years of age or older)

OPT OUT

What is your study discipline?

None

This research project is being undertaken by the Interaction Design Centre, during which, industry standard anonymous usage metrics are gathered from all users of this app using Google Analytics Mobile software.

All usage metrics data and consentual interaction metrics data is anonymous and will be analysed within the strictest confidence in accordance with the Faculty of Science and Engineering Research Ethics Committee guidelines.

Questions regarding this research project can be sent to the primary investigator and researcher Daryl Feehely (daryl.feehely@ul.ie), to the research project supervisor Mikael Fernström (mikael.fernstrom@ul.ie), to the Centre for Teaching & Learning (maura.murphy@ul.ie) or to the Science & Engineering Research Ethics Committee Chairperson (SciEngEthics@ul.ie).

Save and Open the First 7 Weeks App

Figure 72. Consent Form

Appendix C – JSON Responses

Last Content Updated Datestamp JSON Response

{"nodes":[{"node":{"field_date":"2012-09-16 21:26:01"}}]}

Page Node JSON Response

{"vid":"10","uid":"1","title":"Week 1. Welcome, Settling In, Finding
Your Way
Around","log":"","status":"1","comment":"1","promote":"0","sticky":"
0","nid":"10","type":"section","language":"und","created":"134489604
9","changed":"1346545337","tnid":"0","translate":"0","revision_times
tamp":"1346545337","revision_uid":"1","field_image":{"und":[{"fid":"
127","alt":"","title":"","width":"480","height":"251","uid":"1","fil
ename":"wk1.jpg","uri":"public://wk1_0.jpg","filemime":"image/jpeg",
"filesize":"25011","status":"1","timestamp":"1346545337","rdf_mappin
g":[]}]},"field_sectionimageurl":{"und":[{"value":"wk1.jpg","format"
:null,"safe_value":"wk1.jpg"}]},"field_sectiontype":{"und":[{"value"
:"week","format":null,"safe_value":"week"}]},"field_sectionorder":{"
und":[{"value":"1"}]},"field_linktype":{"und":[{"value":"page","form
at":null,"safe_value":"page"}]},"field_pageid":{"und":[{"value":"17"
,"format":null,"safe_value":"17"}]},"field_menuparentid":{"und":[{"v
alue":"11","format":null,"safe_value":"11"}]},"field_weeknumber":{"u
nd":[{"value":"1"}]},"field_computed":{"und":[{"value":"page/17"}]},
"rdf_mapping":{"rdftype":["sioc:Item","foaf:Document"],"title":{"pre
dicates":["dc:title"]},"created":{"predicates":["dc:date","dc:create
d"],"datatype":"xsd:dateTime","callback":"date_iso8601"},"changed":{
"predicates":["dc:modified"],"datatype":"xsd:dateTime","callback":"d
ate_iso8601"},"body":{"predicates":["content:encoded"]},"uid":{"pred
icates":["sioc:has_creator"],"type":"rel"},"name":{"predicates":["fo
af:name"]},"comment_count":{"predicates":["sioc:num_replies"],"datat
ype":"xsd:integer"},"last_activity":{"predicates":["sioc:last_activi
ty_date"],"datatype":"xsd:dateTime","callback":"date_iso8601"}},"cid
":"0","last_comment_timestamp":"1344896049","last_comment_name":null
,"last_comment_uid":"1","comment_count":"0","name":"admin","picture"
:"0","data":"b:0;","path":"http://first7weeks.ul.ie/node/10"}

Menu List JSON Response

{"nodes":[{"node":{"title":"Weeks 1 to 7
Information","field_image":"http://first7weeks.ul.ie/sites/default/f
iles/hub_0.jpg","field_sectionimageurl":"hub.jpg","field_linktype":"
menu","nid":"11","field_sectionorder":"1","field_sectiontype":"info"
,"changed":"2012-09-2
01:09:29","field_pageid":"0","field_menuparentid":"0","field_weeknum
ber":""}},{"node":{"title":"Week 1. Welcome, Settling In, Finding
Your Way
Around","field_image":"http://first7weeks.ul.ie/sites/default/files/
wk1_0.jpg","field_sectionimageurl":"wk1.jpg","field_linktype":"page"
,"nid":"10","field_sectionorder":"1","field_sectiontype":"week","cha

nged":"2012-09-2
01:09:17","field_pageid":"17","field_menuparentid":"11","field_weeknumber":"1"}},{"node":{"title":"Wk 2. Study Skills and Time Management","field_image":"http://first7weeks.ul.ie/sites/default/files/wk2_0.jpg","field_sectionimageurl":"wk2.jpg","field_linktype":"page","nid":"40","field_sectionorder":"2","field_sectiontype":"week","changed":"2012-09-2
01:09:08","field_pageid":"39","field_menuparentid":"11","field_weeknumber":"2"}},{"node":{"title":"About the F7W Programme","field_image":"http://first7weeks.ul.ie/sites/default/files/about_0.jpg","field_sectionimageurl":"about.jpg","field_linktype":"page","nid":"12","field_sectionorder":"2","field_sectiontype":"info","changed":"2012-09-2
18:09:55","field_pageid":"14","field_menuparentid":"0","field_weeknumber":""}},{"node":{"title":"Recommended Books","field_image":"http://first7weeks.ul.ie/sites/default/files/books_0.jpg","field_sectionimageurl":"books.jpg","field_linktype":"page","nid":"52","field_sectionorder":"3","field_sectiontype":"info","changed":"2012-09-2
02:09:53","field_pageid":"51","field_menuparentid":"0","field_weeknumber":""}},{"node":{"title":"Wk 3. Health and Wellbeing","field_image":"http://first7weeks.ul.ie/sites/default/files/wk3_0.jpg","field_sectionimageurl":"wk3.jpg","field_linktype":"page","nid":"42","field_sectionorder":"3","field_sectiontype":"week","changed":"2012-09-2
01:09:12","field_pageid":"41","field_menuparentid":"11","field_weeknumber":"3"}},{"node":{"title":"President's Message","field_image":"http://first7weeks.ul.ie/sites/default/files/president_0.jpg","field_sectionimageurl":"president.jpg","field_linktype":"page","nid":"13","field_sectionorder":"3","field_sectiontype":"info","changed":"2012-09-2
02:09:51","field_pageid":"15","field_menuparentid":"0","field_weeknumber":""}},{"node":{"title":"Wk 4. Meet Your Advisor","field_image":"http://first7weeks.ul.ie/sites/default/files/wk4_0.jpg","field_sectionimageurl":"wk4.jpg","field_linktype":"page","nid":"44","field_sectionorder":"4","field_sectiontype":"week","changed":"2012-09-2
01:09:30","field_pageid":"43","field_menuparentid":"11","field_weeknumber":"4"}},{"node":{"title":"Wk 5. Learner Support Centres","field_image":"http://first7weeks.ul.ie/sites/default/files/wk5_0.jpg","field_sectionimageurl":"wk5.jpg","field_linktype":"page","nid":"46","field_sectionorder":"5","field_sectiontype":"week","changed":"2012-09-2
01:09:58","field_pageid":"45","field_menuparentid":"11","field_weeknumber":"5"}},{"node":{"title":"Wk 6. Career, Civic Engagement and Volunteering Awareness","field_image":"http://first7weeks.ul.ie/sites/default/files/wk6_1.jpg","field_sectionimageurl":"wk6.jpg","field_linktype":"page","nid":"48","field_sectionorder":"6","field_sectiontype":"week","changed":"2012-09-2
01:09:04","field_pageid":"47","field_menuparentid":"11","field_weeknumber":"6"}},{"node":{"title":"Wk 7. Critical Thinking and Longer Term Planning","field_image":"http://first7weeks.ul.ie/sites/default/files/wk7_0.jpg","field_sectionimageurl":"wk7.jpg","field_linktype":"page","nid":"50","field_sectionorder":"7","field_sectiontype":"week","changed":"2012-09-2
01:09:42","field_pageid":"49","field_menuparentid":"11","field_weeknumber":"7"}}]}

Appendix D – Map File Definitions & Code Structures

D.1. Floormap Example File

{"map":{
"i": "10",
"v": "1",
"d": "1208051324",
"m": "Main Building [G]",
"n":[
{"i":"1", "t":"1", "x":"0", "y":"0", "z":"0",
"n1":"2","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"5", "ex":"1", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":"110"},
{"i":"2", "t":"6", "x":"0", "y":"-20", "z":"0",
"n1":"","n2":"","n3":"17","n4":"","n5":"","n6":"","n7":"3","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"3", "t":"6", "x":"-40", "y":"-20", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"4","n8":"5", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"1","r9":""},
{"i":"4", "t":"3", "x":"-60", "y":"-20", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"1", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"5", "t":"2", "x":"-100", "y":"-80", "z":"0",
"n1":"","n2":"","n3":"","n4":"1","n5":"","n6":"","n7":"15","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"1","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"6", "t":"3", "x":"-140", "y":"-60", "z":"0",
"n1":"","n2":"","n3":"16","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"1", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"7", "t":"6", "x":"-200", "y":"-80", "z":"0",
"n1":"","n2":"","n3":"15","n4":"","n5":"12","n6":"","n7":"8","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"2,3","r4":"","r5":"11","r6":"","r7":"4,5,6,7,8,9","r8":"","r9":""},
{"i":"8", "t":"2", "x":"-400", "y":"-80", "z":"0",
"n1":"","n2":"","n3":"7","n4":"","n5":"9","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"4,5,6,7,8,9","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"9", "t":"5", "x":"-400", "y":"-60", "z":"0",
"n1":"8","n2":"","n3":"10","n4":"","n5":"11","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":"10"},
{"i":"10", "t":"3", "x":"-380", "y":"-60", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"9","n8":"", "en":"", "ex":"", "u":"1", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"11", "t":"1", "x":"-400", "y":"-40", "z":"0",
"n1":"9","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"5", "ex":"1", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":"111"},
{"i":"12", "t":"5", "x":"-200", "y":"140", "z":"0",
"n1":"7","n2":"","n3":"14","n4":"","n5":"13","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"11","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"13", "t":"3", "x":"-200", "y":"160", "z":"0",
"n1":"12","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"14", "t":"1", "x":"-180", "y":"140", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"12","n8":"", "en":"3", "ex":"7", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":"112"},

{"i":"15", "t":"6", "x":"-120", "y":"-80", "z":"0",
"n1":"","n2":"","n3":"5","n4":"","n5":"16","n6":"","n7":"7","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"2,3","r8":"","r9":""},
{"i":"16", "t":"5", "x":"-120", "y":"-60", "z":"0",
"n1":"15","n2":"","n3":"5","n4":"","n5":"81","n6":"","n7":"6","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"17", "t":"6", "x":"40", "y":"-20", "z":"0",
"n1":"","n2":"19","n3":"18","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"1,12","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"18", "t":"3", "x":"60", "y":"-20", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"17","n8":"", "en":"", "ex":"", "u":"1", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"19", "t":"2", "x":"100", "y":"-80", "z":"0",
"n1":"","n2":"","n3":"20","n4":"","n5":"","n6":"17","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"13","r4":"","r5":"","r6":"1,12","r7":"","r8":"","r9":""},
{"i":"20", "t":"6", "x":"120", "y":"-80", "z":"0",
"n1":"","n2":"","n3":"23","n4":"","n5":"21","n6":"","n7":"19","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"13","r8":"","r9":""},
{"i":"21", "t":"5", "x":"120", "y":"-60", "z":"0",
"n1":"20","n2":"","n3":"22","n4":"","n5":"40","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"22", "t":"3", "x":"140", "y":"-60", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"21","n8":"", "en":"", "ex":"", "u":"1", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"23", "t":"6", "x":"140", "y":"-80", "z":"0",
"n1":"24","n2":"","n3":"25","n4":"","n5":"","n6":"","n7":"20","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"24", "t":"4", "x":"140", "y":"-100", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"23","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"1", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":"246"},
{"i":"25", "t":"6", "x":"180", "y":"-80", "z":"0",
"n1":"","n2":"","n3":"","n4":"26","n5":"","n6":"","n7":"23","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"16,18,19,21","r5":"","r6":"","r7":"","r8":"","r9":"22"},
{"i":"26", "t":"6", "x":"280", "y":"20", "z":"0",
"n1":"28","n2":"","n3":"","n4":"27","n5":"","n6":"","n7":"","n8":"25", "en":"", "ex":"", "u":"", "d":"",
"r1":"17,16,15,22,23","r2":"","r3":"","r4":"24,25,26,27,17","r5":"","r6":"","r7":"","r8":"16,18,19,21",
"r9":""},
{"i":"27", "t":"6", "x":"360", "y":"100", "z":"0",
"n1":"","n2":"","n3":"29","n4":"","n5":"","n6":"","n7":"30","n8":"26", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"24,25,26,27,17","r8":"24","r9":""},
{"i":"28", "t":"6", "x":"280", "y":"-200", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"26","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"17,16,15,22,23","r6":"","r7":"","r8":"","r9":""},
{"i":"29", "t":"1", "x":"380", "y":"100", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"27","n8":"", "en":"3", "ex":"7", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"30", "t":"5", "x":"180", "y":"100", "z":"0",
"n1":"","n2":"","n3":"27","n4":"","n5":"32","n6":"","n7":"31","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"25,26,27","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"31", "t":"1", "x":"140", "y":"100", "z":"0",
"n1":"","n2":"","n3":"30","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"7", "ex":"3", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":"115"},
{"i":"32", "t":"3", "x":"180", "y":"120", "z":"0",
"n1":"30","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"1", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},

{"i":"33", "t":"1", "x":"360", "y":"-100", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"34","n6":"","n7":"","n8":"", "en":"1", "ex":"5", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":"116"},
{"i":"34", "t":"5", "x":"360", "y":"-80", "z":"0",
"n1":"33","n2":"","n3":"","n4":"","n5":"35","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"35", "t":"3", "x":"360", "y":"-60", "z":"0",
"n1":"34","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"1", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"36", "t":"1", "x":"240", "y":"280", "z":"0",
"n1":"37","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"5", "ex":"1", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"37", "t":"6", "x":"240", "y":"260", "z":"0",
"n1":"39","n2":"","n3":"","n4":"","n5":"36","n6":"","n7":"38","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"28,29,30,31,32,33","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"38", "t":"3", "x":"220", "y":"260", "z":"0",
"n1":"","n2":"","n3":"37","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"1", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":""},
{"i":"39", "t":"6", "x":"240", "y":"140", "z":"0",
"n1":"","n2":"","n3":"","n4":"","n5":"37","n6":"","n7":"","n8":"", "en":"", "ex":"", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"28,29,30,31,32,33","r6":"","r7":"","r8":"","r9":""},
{"i":"40", "t":"1", "x":"120", "y":"-20", "z":"0",
"n1":"21","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"5", "ex":"1", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":"114"},
{"i":"81", "t":"1", "x":"-120", "y":"-40", "z":"0",
"n1":"16","n2":"","n3":"","n4":"","n5":"","n6":"","n7":"","n8":"", "en":"5", "ex":"1", "u":"", "d":"",
"r1":"","r2":"","r3":"","r4":"","r5":"","r6":"","r7":"","r8":"","r9":"113"}
],
"s":[
{"i":"1","t":"1","x1":"-220","y1":"-840","x2":"260","y2":"-580","r":"","c":"#404040"},
{"i":"2","t":"1","x1":"200","y1":"-578","x2":"520","y2":"-300","r":"","c":"#303030"},
{"i":"3","t":"1","x1":"140","y1":"-298","x2":"380","y2":"280.00f","r":"","c":"#404040"},
{"i":"4","t":"1","x1":"-178","y1":"-180","x2":"138","y2":"0","r":"","c":"#303030"},
{"i":"5","t":"1","x1":"-420","y1":"-260","x2":"-180","y2":"180","r":"","c":"#404040"}

],
"t":[
{"i":"1","x":"-20","y":"-540","t":"A","s":"40","c":"#404040"},
{"i":"2","x":"160","y":"-420","t":"B","s":"40","c":"#303030"},
{"i":"3","x":"100","y":"-260","t":"C","s":"40","c":"#404040"},
{"i":"4","x":"-20","y":"-200","t":"D","s":"40","c":"#303030"},
{"i":"5","x":"-320","y":"-270","t":"E","s":"40","c":"#404040"},
{"i":"6","x":"-110","y":"70","t":"Main Building","s":"30","c":"#404040"},
{"i":"7","x":"-65","y":"110","t":"Floor G","s":"30","c":"#404040"}
]
}}

D.2. Room List Example File

{"room":{
"i": "1",
"v": "1",
"d": "12072520052",
"m": "Main Building Level G",
"r":[

{"i":"1", "t":"9", "te":"DG-016", "d":"Jean Monnet"},
{"i":"2", "t":"3", "te":"DG-012", "d":"Female Toilet"},
{"i":"3", "t":"3", "te":"DG-013", "d":"Accessible Toilet"},
{"i":"4", "t":"8", "te":"EG-001", "d":""},
{"i":"5", "t":"1", "te":"EG-002", "d":""},
{"i":"6", "t":"1", "te":"EG-003", "d":""},
{"i":"7", "t":"1", "te":"EG-004", "d":""},
{"i":"8", "t":"1", "te":"EG-005", "d":""},
{"i":"9", "t":"8", "te":"EG-006", "d":""},
{"i":"10", "t":"2", "te":"EG-007", "d":"Male Toilet"},
{"i":"11", "t":"12", "te":"EG-010", "d":""},
{"i":"12", "t":"1", "te":"DG-018", "d":"Main Reception"},
{"i":"13", "t":"2", "te":"DG-020", "d":"Male Toilet"},
{"i":"14", "t":"10", "te":"CG-022", "d":"Lab"},
{"i":"15", "t":"10", "te":"CG-024", "d":"Lab"},
{"i":"16", "t":"10", "te":"CG-029", "d":"Lab"},
{"i":"17", "t":"13", "te":"CG-030", "d":"Workshop"},
{"i":"18", "t":"13", "te":"CG-042", "d":"Workshop"},
{"i":"19", "t":"13", "te":"CG-044", "d":"Workshop"},
{"i":"20", "t":"10", "te":"CG-047", "d":"Lab"},
{"i":"21", "t":"13", "te":"CG-048", "d":"Workshop"},
{"i":"22", "t":"1", "te":"CG-023", "d":""},
{"i":"23", "t":"1", "te":"CG-025", "d":""},
{"i":"24", "t":"1", "te":"CG-036", "d":""},
{"i":"25", "t":"1", "te":"CG-035", "d":""},
{"i":"26", "t":"1", "te":"CG-037", "d":""},
{"i":"27", "t":"1", "te":"CG-038", "d":""},
{"i":"28", "t":"1", "te":"CG-053", "d":""},
{"i":"29", "t":"1", "te":"CG-054", "d":""},
{"i":"30", "t":"1", "te":"CG-055", "d":""},
{"i":"31", "t":"1", "te":"CG-057", "d":""},
{"i":"32", "t":"1", "te":"CG-058", "d":""},
{"i":"33", "t":"1", "te":"CG-059", "d":""},
{"i":"110", "t":"14", "te":"", "d":"Main Entrance"},
{"i":"111", "t":"14", "te":"Murphy Tower", "d":"Entrance"},
{"i":"112", "t":"14", "te":"Harvey Tower", "d":"Entrance"},
{"i":"113", "t":"14", "te":"Dargan Tower", "d":"Entrance"},
{"i":"114", "t":"14", "te":"Merriman Tower", "d":"Entrance"},
{"i":"115", "t":"14", "te":"Burke Tower", "d":"Entrance"},
{"i":"116", "t":"14", "te":"Boyle Tower", "d":"Entrance"},
{"i":"246", "t":"15", "te":"Floor G", "d":"Lift"}
]
}}

D.3. QR Code List Example File

{"codes":{
"i": "1",
"v": "1",
"d": "1209011550",
"m": "QR codes",
"n":[
{"qr":"1", "n":"3", "m":"1", "l":"0"},
{"qr":"2", "n":"2", "m":"2", "l":"0"},
{"qr":"2", "n":"3", "m":"3", "l":"0"},

{"qr":"4", "n":"7", "m":"4", "l":"1"},
{"qr":"5", "n":"2", "m":"5", "l":"1"},
{"qr":"6", "n":"2", "m":"6", "l":"1"},
{"qr":"7", "n":"2", "m":"7", "l":"1"},
{"qr":"8", "n":"2", "m":"8", "l":"0"},
{"qr":"9", "n":"2", "m":"9", "l":"0"},
{"qr":"10", "n":"7", "m":"10", "l":"0"},
{"qr":"20", "n":"12", "m":"10", "l":"0"},
{"qr":"21", "n":"9", "m":"10", "l":"0"},
{"qr":"22", "n":"16", "m":"10", "l":"0"},
{"qr":"23", "n":"21", "m":"10", "l":"0"},
{"qr":"24", "n":"30", "m":"10", "l":"0"},
{"qr":"25", "n":"34", "m":"10", "l":"0"},
{"qr":"26", "n":"51", "m":"10", "l":"1"},
{"qr":"27", "n":"47", "m":"10", "l":"1"},
{"qr":"28", "n":"61", "m":"10", "l":"1"},
{"qr":"29", "n":"68", "m":"10", "l":"1"},
{"qr":"30", "n":"79", "m":"10", "l":"1"},
{"qr":"31", "n":"88", "m":"10", "l":"1"},
{"qr":"32", "n":"91", "m":"10", "l":"1"},
{"qr":"33", "n":"110", "m":"10", "l":"1"},
{"qr":"34", "n":"95", "m":"10", "l":"1"},
{"qr":"35", "n":"101", "m":"10", "l":"1"},
{"qr":"36", "n":"105", "m":"10", "l":"1"},
{"qr":"37", "n":"114", "m":"10", "l":"1"},
{"qr":"75", "n":"54", "m":"10", "l":"1"},
{"qr":"38", "n":"168", "m":"10", "l":"2"},
{"qr":"39", "n":"166", "m":"10", "l":"2"},
{"qr":"40", "n":"172", "m":"10", "l":"2"},
{"qr":"41", "n":"161", "m":"10", "l":"2"},
{"qr":"42", "n":"159", "m":"10", "l":"2"},
{"qr":"43", "n":"155", "m":"10", "l":"2"},
{"qr":"44", "n":"151", "m":"10", "l":"2"},
{"qr":"45", "n":"149", "m":"10", "l":"2"},
{"qr":"46", "n":"142", "m":"10", "l":"2"},
{"qr":"47", "n":"123", "m":"10", "l":"2"},
{"qr":"48", "n":"127", "m":"10", "l":"2"},
{"qr":"49", "n":"133", "m":"10", "l":"2"},
{"qr":"50", "n":"135", "m":"10", "l":"2"},
{"qr":"51", "n":"188", "m":"10", "l":"3"},
{"qr":"52", "n":"181", "m":"10", "l":"3"},
{"qr":"53", "n":"177", "m":"10", "l":"3"},
{"qr":"54", "n":"184", "m":"10", "l":"3"},
{"qr":"55", "n":"196", "m":"10", "l":"3"},
{"qr":"56", "n":"199", "m":"10", "l":"3"},
{"qr":"57", "n":"201", "m":"10", "l":"3"},
{"qr":"58", "n":"204", "m":"10", "l":"3"},
{"qr":"59", "n":"208", "m":"10", "l":"3"},
{"qr":"60", "n":"214", "m":"10", "l":"3"},
{"qr":"61", "n":"222", "m":"10", "l":"3"},
{"qr":"62", "n":"219", "m":"10", "l":"3"},
{"qr":"63", "n":"226", "m":"10", "l":"3"},
{"qr":"64", "n":"261", "m":"10", "l":"4"},
{"qr":"65", "n":"253", "m":"10", "l":"4"},
{"qr":"66", "n":"249", "m":"10", "l":"4"},
{"qr":"67", "n":"246", "m":"10", "l":"4"},

{"qr":"68", "n":"242", "m":"10", "l":"4"},
{"qr":"71", "n":"237", "m":"10", "l":"4"},
{"qr":"72", "n":"230", "m":"10", "l":"4"},
{"qr":"73", "n":"233", "m":"10", "l":"4"},
{"qr":"76", "n":"264", "m":"10", "l":"5"},
{"qr":"77", "n":"269", "m":"10", "l":"5"},
{"qr":"78", "n":"271", "m":"10", "l":"5"}
]
}}

D.4. Code Structures

D.4.1. F7WMap_Tree Class

```
package com.ul.idc.F7W;
import java.util.ArrayList;
import java.util.HashMap;
import android.graphics.Path;
public class F7WMap_Tree {
	public HashMap<Long , F7WMap_Node> nodes = new HashMap<Long , F7WMap_Node>();
	public HashMap<Long , F7WMap_Room> rooms = new HashMap<Long ,
F7WMap_Room>();
	public HashMap<Long , F7WMap_Shape> shapes = new HashMap<Long ,
F7WMap_Shape>();
	public HashMap<Long , F7WMap_Text> texts = new HashMap<Long , F7WMap_Text>();
	public ArrayList<Path> paths = new ArrayList<Path>();
	public F7WMap_Tree() {
	}
}
```

D.4.2. F7WMap_Node Class

```
package com.ul.idc.F7W;
public class F7WMap_Node {
	public static final int ENTRANCE_EXIT = 1;
	public static final int DOORWAY = 2;
	public static final int STAIRWELL = 3;
	public static final int LIFT = 4;
	public static final int MAPPOINT = 5;
	public static final int MIDNODE = 6;
	public static final int TUNNEL = 7;
	public long nodeID;
	public int type;
	public float x;
	public float y;
	public float z;
	public int entryVector;
	public int exitVector;
	public int upLevel;
	public int downLevel;
	public long[] connectedNodes = new long[8];//0=N,1=NE,2=E,3=SE,4=S,5=SW,6=W,7=NW
	public String[] connectedRooms = new
String[9];//0=N,1=NE,2=E,3=SE,4=S,5=SW,6=W,7=NW, 8=this node
	public F7WMap_Node() {
	}
}
```

D.4.3. F7WMap_Room Class

```
package com.ul.idc.F7W;
import java.util.ArrayList;
public class F7WMap_Room {
	public static final int ROOM = 1;
	public static final int TOILET_MALE = 2;
	public static final int TOILET_FEMALE = 3;
	public static final int TOILET_DISABLED = 4;
	public static final int TOILET_BOTH = 5;
	public static final int TOILET_ALL = 6;
	public static final int OFFICE = 7;
	public static final int CLASSROOM = 8;
	public static final int LECTUREHALL = 9;
	public static final int LAB = 10;
	public static final int FOOD = 11;
	public static final int HALL = 12;
	public static final int WORKSHOP = 13;
	public static final int ENTRANCE_EXIT = 14;
	public static final int LIFT = 15;
	public static final int STAIRWELL = 16;
	public long roomID;
	public int type;
	public int buildingID;
	public int level;
	public String title;
	public String description;
	public ArrayList<Long> nodePositions = new ArrayList<Long>();
	//0 only=node position, 0+1=between nodes
	public F7WMap_Room() {
	}
	@Override
	public String toString(){
		return title + " "+ description;
	}
}
```

D.4.4. F7WMap_Shape Class

```
package com.ul.idc.F7W;
public class F7WMap_Shape {
	public static final int RECTANGLE = 1;
	public static final int CIRCLE = 2;
	public long shapeID;
	public int type;
	public float x1;
	public float y1;
	public float x2;
	public float y2;
	public float r;
```

```
        public String colour;
        public F7WMap_Shape() {
        }
}
```

D.4.5. F7WMap_Text Class

```
package com.ul.idc.F7W;
public class F7WMap_Text {

        public long textID;
        public float x;
        public float y;
        public String text;
        public int textSize;
        public String colour;
        public F7WMap_Text() {
        }
}
```

D.4.6. F7WMap_QRCode Class

```
package com.ul.idc.F7W;
public class F7WMap_QRCode {
        public long qrID;
        public long nodeID;
        public int mapID;
        public int levelID;
        public F7WMap_QRCode() {
        }
}
```

Appendix E – Example QR Code Poster

Figure 73. QR Code Poster

Appendix F – Logging Data Schema and Format

F.1. Logging Data Schema

```
Map_[mapID], Scan_[floorID], clicked
Map_[mapID], StartSet_[floorID], set
Map_[mapID], EndSet_[floorID], set
Map_[mapID], Clear_[floorID], clicked
Map_[mapID], Exit_[floorID], clicked
Map_[mapID], Help_[floorID], clicked
Map_[mapID], Rooms_[floorID], clicked
Map_[mapID], Rooms_[floorID]_[roomID], selected
Map_[mapID], Rooms_[floorID]_[roomID], selected
Map_[mapID], Rooms_[floorID], direction_selected_[roomID]
Map_[mapID], Nodes_[floorID], clicked_[nodeID]
Map_[mapID], Nodes_[floorID], up_[nodeID]
Map_[mapID], Nodes_[floorID], down_[nodeID]
Map_[mapID], Nodes_[floorID], direction_1_[nodeID]
Map_[mapID], Nodes_[floorID], direction_2_[nodeID]
Map_[mapID], Nodes_[floorID], direction_3_[nodeID]
Map_[mapID], Nodes_[floorID], direction_4_[nodeID]
Map_[mapID], Nodes_[floorID], direction_5_[nodeID]
Map_[mapID], Nodes_[floorID], direction_6_[nodeID]
Map_[mapID], Nodes_[floorID], direction_7_[nodeID]
Map_[mapID], Nodes_[floorID], direction_8_[nodeID]
Map_[mapID], Nodes_[floorID], direction_9_[nodeID]
Map_[mapID], Nodes_[floorID], route_start_[nodeID]
Map_[mapID], Nodes_[floorID], route_start_cancel_[nodeID]
Map_[mapID], Nodes_[floorID], route_start_clear
Map_[mapID], Nodes_[floorID], route_end_[nodeID]
Map_[mapID], Nodes_[floorID], route_end_cancel_[nodeID]
Map_[mapID], Nodes_[floorID], route_end_clear

MapHelp, Show_[count], clicked

Refresh, Home, clicked
Refresh, Home, checking
Refresh, Home, silent-checking
Refresh, Home, no connection
Refresh, Home, no connection – silent
Refresh, Home, downloading
Refresh, Menu, clicked
Refresh, Menu, downloading
Refresh, Menu, no connection
Refresh, Updates, Yes
Refresh, Updates, No

Updates, Home, killing
Updates, Home, downloading
LogUpload, Home, uploading

Page_[pageID], Node_[nodeID], info clicked
Page_[pageID], Node_[nodeID], videos clicked
Page_[pageID], Node_[nodeID], photos clicked
Page_[pageID], Node_[nodeID], docs clicked
Page_[pageID], Node_[nodeID], killing loading dialog
```

```
Disclaimer, View, clicked
Disclaimer, []_to_[], update
Disclaimer, [], save

StudyDiscipline, []_to_[], update
StudyDiscipline, [], save
```

F.2. Logging Data Format

```
DeviceID, Date, Type, MapID, PageID, Entity, FloorID, NodeID, RoomID, Count,
NewValue, OldValue, Action
```

Appendix G – Route Planner Source Code

```
package com.ul.idc.F7W;

import java.util.ArrayList;
import java.util.HashMap;
import android.content.Context;
import android.graphics.Path;
import android.widget.Toast;

public class RouteFinder {
	public F7WMap_Tree mapTree = new F7WMap_Tree();
	public Context mContext = null;
	public ArrayList<Long> SettledNodes = new ArrayList<Long>();
	public ArrayList<Long> UnsettledNodes = new ArrayList<Long>();
	F7WMap_Node source = new F7WMap_Node();
	F7WMap_Node destination = new F7WMap_Node();
	HashMap<Long, F7WMap_Node> routeNodesList = new HashMap<Long,
F7WMap_Node>();
	HashMap<Long, Float> dist = new HashMap<Long, Float>();
	HashMap<Long, Long> predecessors = new HashMap<Long, Long>();
	private float mInfinite = 10000;
	private F7WTracker tracker;
	private float distFromSource = mInfinite;
	private float lowestDistFromSource = mInfinite;
	public	ArrayList<Path> routePaths = new ArrayList<Path>();

	public RouteFinder(Context context, F7WMap map) {
		tracker = new F7WTracker(context);
		mapTree.nodes = map.mapTree.nodes;
		mapTree.paths = map.mapTree.paths;
	}

	public HashMap<Long, F7WMap_Node> findRoute(F7WMap_Node src,
F7WMap_Node dest) {
		F7WMap_Node evalNode;

		source = src;
		destination = dest;

		if(source != null && destination != null) {
			UnsettledNodes.clear();
			UnsettledNodes.add(source.nodeID);
			dist.put(source.nodeID, mInfinite);

			while(UnsettledNodes.size() > 0) {
				evalNode =
getNodeWithLowestDistance(UnsettledNodes);

				if(evalNode.nodeID == 0) {
					UnsettledNodes.clear();
				}
				UnsettledNodes.remove(evalNode.nodeID);
				if(!SettledNodes.contains(evalNode.nodeID)) {
					SettledNodes.add(evalNode.nodeID);

				}
```

```
                            if(evalNode.nodeID == destination.nodeID) {
                                  UnsettledNodes.clear();
                            } else {
                                  evaluatedNeighbours(evalNode);
                            }
                      }

                      F7WMap_Node predecessorNode;
                      long predecessor = destination.nodeID;
                      Path path = new Path();
                      path.moveTo(destination.x, destination.y);
                      //backtrack on predecessor list
                      while(predecessor != source.nodeID) {
                            if(mapTree.nodes.containsKey(predecessor)) {
                                  predecessorNode =
mapTree.nodes.get(predecessor);
                                  if(predecessorNode!= null) {
                                        path.lineTo(predecessorNode.x,
predecessorNode.y);
                                        routePaths.add(path);
                                        path = new Path();
                                        path.moveTo(predecessorNode.x,
predecessorNode.y);

                                        routeNodesList.put(predecessor,
predecessorNode);

      if(predecessors.containsKey(predecessor)) {
                                              predecessor =
predecessors.get(predecessor);
                                        } else {
                                              //if we don't have a
predecessor, nodes are not connected, stop path at last valid node
                                              predecessor = 0;
                                              source = predecessorNode;
                                        }
                                  } else {
                                        Toast.makeText(mContext, "No direct
route on this level", Toast.LENGTH_SHORT).show();
                                        break;
                                  }
                            } else {
                                  Toast.makeText(mContext, "No direct route
on this level", Toast.LENGTH_SHORT).show();
                                  break;
                            }
                      }
                      path.lineTo(source.x, source.y);
                      routePaths.add(path);
                      routeNodesList.put(source.nodeID, source);
                }



                return routeNodesList;
      }

      public F7WMap_Node getNodeWithLowestDistance(ArrayList<Long>
```

```
UnsettledNodes) {
		F7WMap_Node result = new F7WMap_Node();
		F7WMap_Node unsettledNode = null;
		F7WMap_Node neighbour = null;
		float neighbourDist = mInfinite;
		float lowestDist = mInfinite;

		for(long unsettledNodeID : UnsettledNodes) {
			unsettledNode =  mapTree.nodes.get(unsettledNodeID);
			if(unsettledNode != null) {

				if(dist.containsKey(unsettledNode.nodeID)) {
					neighbourDist =
dist.get(unsettledNode.nodeID);
				} else {
					neighbourDist = mInfinite;
				}


				if(lowestDist >= neighbourDist) {
					lowestDist = neighbourDist;
					result = unsettledNode;
				}
			}
		}
		distFromSource = lowestDist;
		return result;
	}

	public void evaluatedNeighbours(F7WMap_Node evalNode) {
		F7WMap_Node neighbour = null;
		float neighbourDist = 0;
		float newDist = 0;

		for(int i=0; i < evalNode.connectedNodes.length; i++) {
			if(!SettledNodes.contains(evalNode.connectedNodes[i]))
{
				neighbour =
mapTree.nodes.get(evalNode.connectedNodes[i]);
				if(neighbour != null) {
					neighbourDist = getDistance(evalNode,
neighbour);

					if(evalNode.nodeID == source.nodeID) {
						newDist = neighbourDist;
					} else {
						newDist = distFromSource +
neighbourDist;
					}

					dist.put(neighbour.nodeID, newDist);
//distance to this from source (dist to eval from source + dist from eval
to this)
					predecessors.put(neighbour.nodeID,
evalNode.nodeID);

					if (lowestDistFromSource  > newDist) {
						lowestDistFromSource = newDist;
```

```
                                }

        if(!UnsettledNodes.contains(neighbour.nodeID)) {

        UnsettledNodes.add(neighbour.nodeID);
                                }

                        }
                }
            }
        }

        public float getDistance(F7WMap_Node src, F7WMap_Node dest) {
                float dx = dest.x - src.x;
                float dy = dest.y - src.y;
                float calc = (dx*dx) + (dy*dy);
                float distance = (float)Math.sqrt(calc);
                return distance;
        }
}
```

Figure 74. Route Planner Java Source Code

Appendix H – User Interview Experiment

H.1. Consent Form

FIRST SEVEN WEEKS MOBILE APP INTERVIEW INFORMATION &

CONSENT DISCLAIMER SHEET

The purpose of this study is to evaluate the First Seven Weeks Android app and mobile website, and in particular to gather information about how the mapping functionality of the app is used by participants.

The interview will be conducted face to face by the primary investigator and research (Daryl Feehely) and should last no longer than 30 minutes. All data collected is anonymised and handled in the strictest of confidence. Any recordings taken during the interview process are for transcription only and will not be shared or published.

The interview process is completely voluntary and there is no risk to participants. All participants are free to opt out at any time.

Questions or concerns regarding this research project can be sent to the primary investigator and researcher Daryl Feehely (daryl.feehely@ul.ie), to the research project supervisor Mikael Fernström (mikael.fernstrom@ul.ie), to the Centre for Teaching & Learning (maura.murphy@ul.ie) or to the Science & Engineering Research Ethics Committee Chairperson (SciEngEthics@ul.ie).

H.2. Interview Test Plan

H.2.1. Participant Sampling

An invitation of participation will be extended to the 28 questionnaire participants who expressed an interest in answered further questions when they entered their email address in the second student questionnaire.

H.2.2. Methodology

Within subjects method to be used, whereby each participant or group of participants will be asked to perform a set of tasks. The order of these tasks will be counterbalanced to reduce the familiarity factor.

H.2.3. Questions & Tasks

1. Have you used the mapping feature of the First Seven Weeks Android app before?
2. Passive Cognitive Walkthrough – ask the user to articulate actions to achieve the following tasks (prompting when needed):
    a. Access weekly F7W information
        i. What is the theme of week 3 and what supports/information are available?
    b. Access the map of the main building
        i. Can you find the map of the main building?
    c. View the list of rooms in the building
        i. Can you view a list of the rooms in the building?
    d. Find where a certain room is in the main building.
        i. Can you find where the Charles Parsons Lecture Hall is?
3. Active Cognitive Walkthrough (Cooperative Evaluation) – ask user to articulate actions while wayfinding.
    a. Find a room from the list, start wayfinding
    b. Tap and explore the map while wayfinding
    c. Plot a route to another location and follow the route to that location

    d. Scan a QR code while wayfinding

4. Post-walk through questions – subjective evaluation
    a. How useful do you think each of these mapping features is (5 point likert scale):
        i. Roomlist
        ii. Tap & Explore
        iii. Routing
        iv. QR code scanning
        v. Map check when not in building
        vi. Displaying general location of rooms instead of precise locations
    b. In terms of learning your way around, how effective is this?
    c. In terms of learning your way around, how effective are all of these?
    d. Does it help reduce the anxiety of being lost?
    e. How often would you see yourself using the mapping features?
    f. Were you frustrated by any of the tasks or did you find any difficult?
    g. Are you satisfied that using the app can help you find your way around?
    h. Do you think it is easy to use?
    i. Did anything surprise you?
    j. Any comments?

H.2.4. Interview Shortcode

B = Begin Task

E = End Task

T = Tap

P = Prompted by Moderator

X = Incorrect Action

CC = Completed Correctly

? = Probe participant during debrief