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Master Thesis: Interactive Solution For Inspiria Science Center

by

Van Hai Nguyen

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in the
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Declaration of Authorship

I, VAN HAI NGUYEN, declare that this thesis titled, 'Interactive Solution For Inspiria Science Center' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at Høgskolen i Østfold.

- Where any part of this thesis has previously been submitted for a degree or any other qualification at Høgskolen i Østfold or any other institution, this has been clearly stated.

- Where I have consulted the published work of others, this is always clearly attributed.

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- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

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Abstract

Faculty of Computer Sciences

Master in Applied Computer Science

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Learning and meaning-making are the basic need coming from human nature. Improving the learning experience with a combination of learning, fun-making, technical aspects were still unsatisfactory. Compared with learning places, museum is one of the best representations based on learning theories, for both knowledge and fun. Through a reviewing and interview, it is found that learning experience at Inspiria museum is not well provided due to no combination of meaning and fun making as well as technical aspects.

Motivated by improving the learning experience at Inspiria museum, a solution based on gaming, augmented, location awareness implemented on platforms of smartphones and tables is proposed and taken into practice. In this thesis, an app so called "Inspiria's App", as the combination of these techniques and Smartphones/tables technology, has been designed and developed.

The design of this application based on experience from similar projects and research on interaction design in recommended system. To evaluate the performance of 'Inspiria App' on the enhancement of learning effect, the usability testing processes with interview, observation were conducted. This app successfully attracted more visitors and provided a more efficient learning experience by realizing the hypothesis of learning by playing.

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For/Dedicated to/To my...

Chapter 1

Introduction

1.1 Motivation

INSPIRIA science center is a popular scientific recreation and learning environment in Sarpsborg for mathematics, science and technology where visitors can learn by experimenting themselves. In a Science Centre, children and adults can explore phenomena related to nature, environment, health and technology through activities on their own or in collaboration with others.

The center aims to encourage young people to choose science and as an important social task. It highlights the importance of experience and knowledge about science and technology. Moreover, the center can be used for other public activities, or as an event venue.

Inspiria can be seen as a science museum exhibits where is no longer just store and preserve objects of significance and value, but are increasingly becoming places where visitors can have an aesthetic, intellectual, learning, even fun experience as Marco Mason [11]. By taking advantage of mobile devices, I aim to design innovative interactive ex-

Figure 1.1: Inspiria Science Center

periences for visitors to make learning easier, faster, more enjoyable, more self-directed,

more effective, and more transferable to new situations that is related to educational issues, pleasurable visitor experiences.

This thesis aims to explore the alternatives of information interactions, with a strong focus on creating engaging experience which enrich the learning experience in museum without stealing the focus away from its attractions.

By merging the content of learning and the motivation produced in games I also want to create a more enjoyable experience. As a result, visitors are motivated to explore museum that they enjoy rather than trying to memorize a list of facts. The game and support functions described in my thesis will encourage learner to seek out the information themselves.

The application designed on mobile devices will allow visitors to have interactive experiences throughout a museum, as well as remote experiences for those who cannot get there. Moreover, it allows real time update of information related to an artefact (e.g., exhibit information, guided tours, special event notification) and a great flexibility of information.

Besides making museums more appealing to individuals, I also want to enhance communication, social interaction, and even technical skills for visitors during the visit.

1.2 Research Question

My main focus is to improve the experience for the visitors of Insipira museum. As an potential technology described in motivation phase, I decided to make an mobile application.

The main research question in my thesis can be summarized as following:

- How can we make a mobile application which improves the conventional way of visiting the museum and encourages visitor participation both onsite andoffsite of the museum space?

The sub-questions of the research is as following:

- What challenges arise when using this mobile application in this museum setting?

- How can a mobile solution enhance museum experience for visitors ?.

1.3 Thesis Overview

In this section, i will describe the organization of the remaining chapters in my thesis.

- Chapter 2: Literature Review

  This chapter presents a literature review on the previous work.

- Chapter 3: Methodology Research

  This chapter presents the methodological background for my thesis.

- Chapter 4: Analysis

  This chapter presents an analysis of systems based on the requirement.

- Chapter 5: Design Phase

  This chapter presents the functionality and design for the mobile solution based on the findings in previous chapters together with storyboarding describing a full interaction of the system.

- Chapter 6: Low-Fidelity Prototype

  This chapter presents Low-Fidelity prototype of system related to concept and functionality.

- Chapter 7: High-Fidelity Prototype

  This chapter presents High-Fidelity Prototype of system and the technology used to create the system, High-Fidelity interface.

- Chapter 8: Usability Testing

  This chapter presents evaluation on the performance of my application that enhance learning effect.

- Chapter 9: Findings

  This chapter presents the findings after conducting usability testing.

- Chapter 10: Discussion

  This chapter presents a discussion on the results and experiences from the usability testing in regard to the research questions defined in my thesis.

- Chapter 11: Conclusion

  And also, this chapter presents the conclusion of this work and proposes ideas for future work.

Chapter 2

Literature Review

In this chapter, i critically review the existing theories and technologies that have been considered and used in order to develop the mobile application related to my system.
In this literature review i highlight the following topics:

- Navigation

- Mapping of digital and real world content

- Game-Based Learning (Educational Game)

- Visualization

2.1 Navigation

Navigation is the process of locating object's position and then presenting a path as well as guide users to destination.
The Global Positioning System (GPS) is the most popular navigation system. However, for indoor environment, GPS satellites could not send a signal to a device if there are solid walls on its path.
Indoor navigation applications for mobile devices are increasingly necessary for users who want to locate something within the building. There are several technologies that can be used together to build a indoor navigation systems. "Current approaches for indoor navigation systems are usually categorized into independent navigation systems and network based navigation systems" [12].
Network based navigation system: GPS/A-GPS, Bluetooth, Ultra Wide Band (UWB), Wi-fi, Radio Frequency Identification (RFID), Infrared or NFC.

Independent navigation system use Dead Reckoning (DR) methods, Vision Navigation method.

2.1.1 Radio Frequency Identification (RFID)

RFID tags are passive and only transmit data if prompted by a reader. The reader transmits radio waves that activate the RFID tag. The tag then transmits information via a pre-determined radio frequency. This information is captured and transmitted to a central database [13].

The RFID technology uses radio frequency to achieve the goal of recognition and positioning by non-contact two-way data communication. On the one hand, it has advantage of big transmission range, low cost and getting information about the location in a few milliseconds. On the other hand, "it has the disadvantage of short effect distance, and lack of the communication ability. Beside, it is also difficult to be integrated into other systems" [14].

For example 1: RSNAVI - An RFID-based Context-aware Indoor Navigation System for the Blind [1], this project provides the architecture of an RFID-based context-aware indoor navigation system for the blind called RSNAVI. It presents a RFID database that recorded possitions of all navi tags, illustrated Figure 2.1.
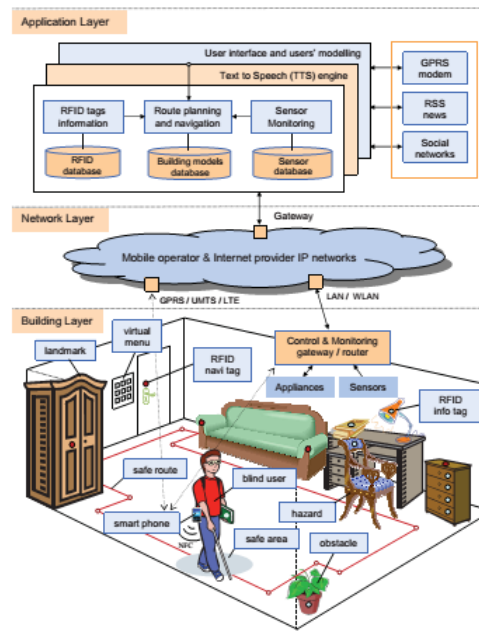
Figure 2.1: RSNAVI architecture [1]

For example 2: Outdoor natural science learning with an RFID-supported immersive ubiquitous learning environment[15].

This project proposed an environment of ubiquitous learning with educational resources

(EULER) based on radio frequency identification (RFID), augmented reality (AR), the Internet, ubiquitous computing, embedded systems, and database technologies.

2.1.2 Wifi

WiFi positioning technologies track positions by measuring the received signal strength. I can category this technology into two different types.

"The first type of method uses the signal strength as an indicator of range. Several Wi-Fi APs with most intensive signal strengths are selected, and their geolocations are requested from the database server of the service provider. And then multilateration is applied on range measurements between user and the selected Wi-Fi APs to calculate user positions. The second type uses the pattern of all received signal strengths as a fingerprint " [16].

The advantage of wifi positioning technology is that it is able to provide both data and location information. However, it requites expensive devices such as access points when i build a location system.

For example 1: ARTLENS[8].

The system detects visitor's location in the museum by indoor wayfiding technology, which uses the nearest wireless access points to triangulate the device's position and offer digital stories about the surrounding artworks.

For example 2: Travi-Navi: Self-deployable Indoor Navigation System[2].

This system implements a vision guided navigation system that enables a user to easily deploy his or her own indoor navigation services. In order to accurately track a follower and generate synchronized directions, this system incorporates both magnetic field distortions and WiFi fingerprint sequences to complement IMU (Inertial Measurement Unit) sensor based dead reckoning and thereby accurately project the follower onto the guider's trace, illustrated Figure 2.2.

For example 3: Intelligent Dynamic Radio Tracking in Indoor Wireless Local Area Networks[17]

For example 4: Predictive Indoor Navigation Using Commercial Smart-phones[18]

This system builds a indoor navigation system based on the general ideas of dead-reckoning and RISS fingerprinting.

2.1.3 Bluetooth

"The Bluetooth, also known as the IEEE 802.15 standard, is a short-range data communication protocol. Similar to cellular telephone systems, Bluetooth devices constitute mini-cells. When the number of installed Bluetooth cells is sufficient, the location of the

Figure 2.2: A usage scenario of Travi-Navi. McD collects traces along aisles in blue, and those by HM are in red. A shortcut (with a red dashed line) between McD and HM is identified from two guiders' traces. [2]

mobile device is considered to be the same as the individual cell that it is communicating with."[12]

The Bluetooth has some merits. "The greatest one of them is the small volume of the device, which makes it easier to be integrated in PC, and mobile devices" [14] and it is able to brings the limited communication data along with the positioning information. Thus its popularization is easier.

However, the devices and equipment of Bluetooth are expensive. Moreover, in the complex place the Bluetooth system is unstable and vulnerable to be interfered by noisy signal [14]. The accuracy depends upon the number of Bluetooth cells and their size.

"The iBeacon is a piece of equipment for indoor positioning issued by Apple Corp in September 2013" [19]. The iBeacon uses Bluetooth low energy proximity sensing to transmit a universally unique identifier picked up by a compatible app or operating system. The identifier can be used to determine the device's physical location, track customers, or trigger a location-based action on the device or a push notification. This technology has improved significantly both accuracy positioning, portability, low power consumption, fast response. Beside, "Ibecacon-based indoor positioning system has merits of both Internet of Things and mobile Internet" [20].

For example 1: iBeacon brings museum to life [21].

The iBeacon tracks position of visitors within the museum. When a visitor is close enough to any art, application will trigger a notification and display information about that art.

For example 2: BlueSentinel - a first approach using iBeacon for an energy efficient occupancy detection system [21].

This system proposes a smart buildings based on iBeacon technology.

2.1.4   Dead Reckoning (DR)

Dead reckoning calculates current position by using a previously determined position, or fix, and advancing that position based upon known or estimated speeds over elapsed time and course.

The advantage of this technology is that it provides a autonomous system and position of user that is always available. Nevertheless, it has large errors (drift and bias) caused by sensors that affect significantly on accuracy of my system.

For example 1: Travi-Navi: Self-deployable Indoor Navigation System[2]

For example 2: Predictive Indoor Navigation Using Commercial Smart-phones[18]

This system builds a indoor navigation system based on the general ideas of dead-reckoning and RISS fingerprinting.

2.1.5   Vision Navigation

This method is based on processing images using algorithms as image recognition, shape identification, edge detection, noise reduction, motion analysis and colour or Mixed Reality technology for navigation.

The advantage of this method is that don't cost too much on hard devices. Using available devices as camera on mobile devices or compass to build system. However, they provide a lower accuracy and depends much on conditions of surrounding environment and quality of devices like camera on mobile phones.

For example 1: Indoor Navigation with Mixed Reality World-in-miniature Views and Sparse Localization on Mobile Devices[3].

This system presents a design of an interface that provides continuous navigational support for indoor scenarios. It combines Mixed Reality technology with mobile device's hardware like camera and screen in order to provide an overview of the whole path, highlight the current position, the path to the destination and the already traversed path (figure 2.3).

For example 2: An Experimental Virtual Museum Based on Augmented Reality and Navigation. [22]

Navigation tasks are supported by an orientation and location scheme, where locations and coordinates of the main elements of each room have been initially captured and stored into a reference XML database which is locally stored in the mobile phone. Locations are tracked by a compass included in the mobile phone device that is then compared to positional information associated to the rooms and objects of the exhibition.
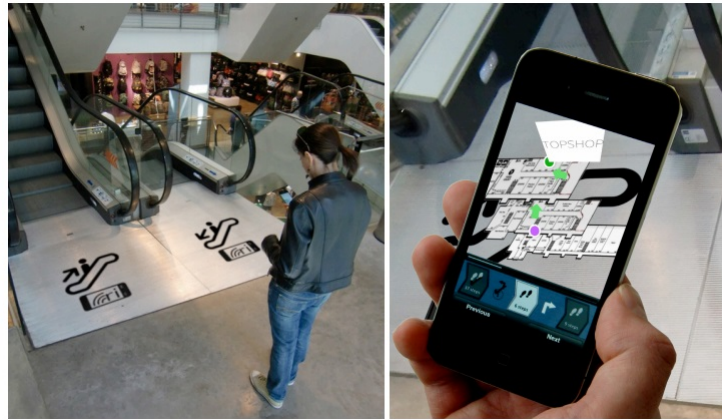
Figure 2.3: Conceptual design of info points for a shopping mall. Left: a user accessing the info point. Right: view on the phone [3]

2.1.6   Summary

Because the iBeacon has the advantages of low cost, accurate positioning, large coverage, and long battery life compared to others like Wifi, RFID (Figure 2.4), I can take advantage and use Ibeacon as trigger method for my system. Fortunately, i can take

	WiFi	RFID	iBeacon
Coverage	50m	10m	50m
Cost	high	Low	A little high
power consumption	high	low	low
Bandwidth	1.8G	250kb	1M
Battery life	Several days	1-2 years	1-2 years
Positioning accuracy	2m-3m	1m-2m	1-2m

Figure 2.4: Comparison of Three Kinds of Common Indoor Positioning Techniques [4]

advantage of Bluetooth right on my mobile devices (Figure 2.5)as a iBeacon device.

Mobile phone operating system	Compatible devices
IOS devices	IOS devices with Bluetooth 4.0 (iPhone 4S and later, iPad (3rd generation) and later, iPad Mini (1st generation) and later, iPod Touch (5th generation).
Android	Android 4.3+ (e.g. Samsung Galaxy S3/S4/S4 Mini, Samsung Galaxy Note 2/3, HTC One, Google/LG Nexus 7 2013 version/Nexus 4/Nexus 5, HTC Butterfly, OnePlus One).
Windows Phone	Windows Phone devices with the Lumia Cyan update or above.

Figure 2.5: All Kinds of Compatible Devices of iBeacon [4]

2.2 Mapping of digital and real world content

As i discussed in "Navigation" session that related to indoor navigation, this session attempts to address the issue that is "How to map digital content to real world locations". In others word, i will build a method to trigger content on device when i accurately identify specific location .

Clearly, users can trigger their device by themselves (manually). However, system on device can base on external events to present particular applications on the displays (automatically). In order to identify and process these events Enrico Rukzio, Gregor Broll, Karin Leichtenstern, Albrecht Schmidt [5] cateloged them by poiting, touching, scanning, point, illustrated Figure 2.6.
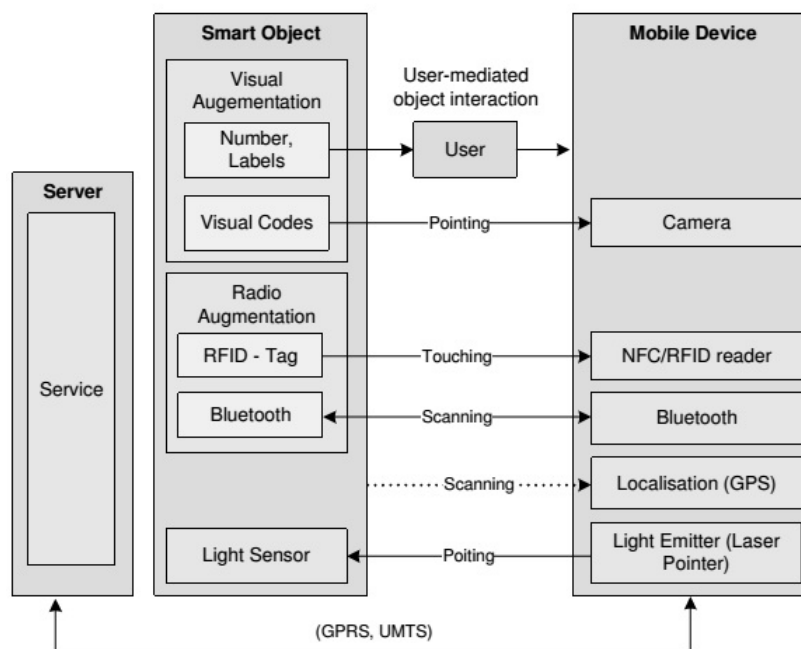
Figure 2.6: Basic architecture used for the implementation of the four prototypes.[5]

2.2.1 Touching

Touching can be used by both Near Field Communication (NFC) technology and RFID. The popular technology used are RFID tags(Radio Frequency IDentification) that is also used in OULO project [23] as a tool to authenticate and trigger, or using NFC that is better tailored to mobile devices. In project of Enrico Rukzio Massimo Paolucci John Hamard Matthias WagnerAlbrecht Schmidt Gregor Broll, Sven Siorpaes [24] whose developed a generic framework to combine services and Physical Mobile Interaction (NFC and RFID)

2.2.2   Pointing

Using the Pointing interaction technique allows the users to select a smart object by aiming at it with a mobile device. Pointing interaction technique can be used by many technologies like mixed reality markers. Alessandro Mulloni, Hartmut Seichter, Dieter Schmalstieg [3] used Mixed Reality marker technology to navigate to destination and trigger digital content whenever camera checks a righ marker on the way to destination. Moreover, Mixed Reality can provide more real experience on knowledge and information that people can interact in real time over long distances. Pointing interaction technique can also be used with QR code, Semacode or visual codes.

2.2.3   Scanning

Scanning is method is used for mobile devices, they scan the environment around them by using wireless mechanism.
The advantage is that the user does not need to be aware of the augmentation of a smart object nor must this object be visually changed to get the attraction of a person. This technology is often implemented with radio frequency communication such as Bluetooth phone services.
iBeacon technology use Bluetooth low energy (LE) to navigate and trigger location-based action on the mobile devices. The ranging function is used to calculate the proximity between an iBeacon and a device that is looking for an iBeacon, this could be used to detect objects such as paintings in a museum and trigger an action [4].

2.2.4   Summary

The scanning technology using iBeacon has the advantages of low power consumption, fast response, and accurate positioning, thus bringing great convenience for both navigation and mapping. I can take advantage of iBeacon technology to trigger content based on the location of users.

2.3   Game-Based Learning

As i discussed in sessions of "Navigation" and "Mapping of digital and real world content", i explored methods to locate my locations (Navigation), and mapping methods to trigger content from digital to real world. In order to enhance visitors' learning and enjoying and map digital to real world, i will explore types of digital content which can use in my project.

2.3.1 Motivation

My focus is on issues in designing innovative interactive experiences for visitors inside Inspiria. Thus, "it is crucial to understand how visitor interpret the museum and the meaning behind exhibits as well as information related to them", Hooper-Greenhill [25]. In other word, the context setting plays an essential role in promoting visitors' learning and enjoying. Tsung-Yu Liu , Yu-Ling Chu described that "incorporating ubiquitous games into the English learning process could achieve a better learning outcomes and motivation than using non-gaming method."[26]. This project implemented a new method for English curriculum that was evaluated on a school campus by using a context-aware ubiquitous learning environment called the Handheld English Language Learning Organization (HELLO).

HELLO helps students to engage in learning activities based on various educational strategies, including ubiquitous game-based learning, collaborative learning, and context aware learning.

The evaluation results of the learning outcomes and learning motivation demonstrated that incorporating ubiquitous games into the English learning process could achieve a better learning outcomes and motivation than using non-gaming method.

Furthermore, Facer, Keri and Joiner, Richard and Stanton, Danaë and Reid, Josephine and Hull, Richard and Kirk, David [27] reported a study that attempts to explore how using mobile technologies in direct physical interaction with space and with other players can be combined with principles of engagement and self-motivation to create a powerful and engaging learning experience. The evaluation on group of kids revealed the findings that mobile gaming might be employed as a tool for supporting learning. Players were fully able to develop strategic and critical thinking in relation to computer games.

"Visitors bring to the museum their preferred learning styles, visiting modes, social groups, and different cultural backgrounds. They make meaning in different ways, have different types and levels of cultural literacy, and bring different experiences and levels of subject knowledge " (Parry 2007 [28]). "They have different expectations for their visit on that specific day to that specific site, and they have different skills and attitudes towards different types of interpretive media" (Marco Mason 2013 [11]).

Moreover, The study in "Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game" conducted by Huizenga, Jantina and Admiraal, Wilfried and Akkerman, Sanne and Dam, G ten [29] showed that the player who played the game to be engaged and to gain significantly more knowledge about medieval Amsterdam than those pupils who received regular project-based instruction. The game called Frequency 1550 in which is "a game about medieval Amsterdam to be played during a single school day. At the start of the game day, the pupils gather at the main location, namely the Waag building or 15th century weighing house in the

city of Amsterdam. The pupils are introduced to the game, the tasks, the tools to be used and the objective of the game: To gain citizenship in the city of Amsterdam via attainment of the required 366 points or 'days of citizenship' which represent the medieval year-and-a-day rule that requires residence within the Amsterdam city walls for this period of time to earn civil rights".

2.3.2 Content

The digital content is a new way to present content in order to convey knowledge and engage visitors. I attempt to carefully consider and integrate various aspects of context, including usability (Understandable, simple, etc.), intellectual (challenging quizzes) accessibility of the digital content. There are already various forms of digital content responding to these issues. One of approach is interactive map introduced by Po-Han Wu Hwang, Gwo-Jen and Hui-Ru Ke [6], this design is used to support mobile learning activities for natural science courses, illustrated Figure 2.8. Students can develop the initial concept map based on what they have learned from their textbooks or in class. Another example, is the OpenStreetMap project, whose aim is to create free road maps based on the work of volunteers who contribute GPS data and trace roads on satellite images or outof-copyright maps. Also, A Cyberguide descibed by Gregory D. Abowd, Christopher G. Atkeson, Jason Hong, Sue Long, Rob Kooper and Mike Pinkerton [30], in which they built prototypes of a mobile context-aware tour guide for indoor and outdoor use on a number of different hand-held platforms as Figure 2.7.

Playing can have an important role in the learning process and using games to this end,
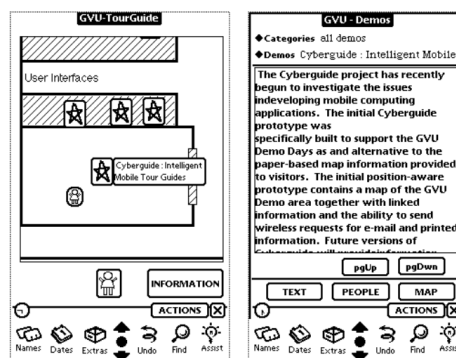
Figure 2.7: The map (left) and information (right) interfaces of the initial Cyberguide MessagePad prototype

is a well-know approach [31]. Adrian Stoica Ioanna Papadimitriou-Nikoleta Yiannoutsou Vassilis Komis Sintoris, Christos and Nikolaos Avouris [32] showed that the physical and digital aspects of pervasive activity were incorporated in a unified experience and the transitions between them were most of the time continuous. Or a augmented real-world
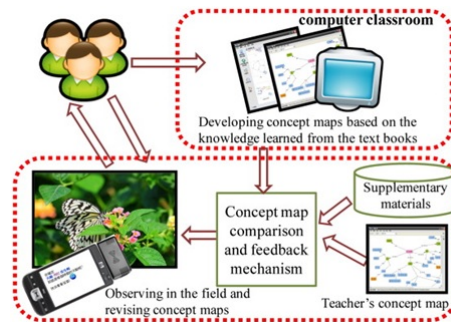
Figure 2.8: System structure of the interactive concept map-oriented mobile learning system.[6]

games, as demonstrated by ARQuake [33] that combines Augmented Reality and classic computer games, so that the players are able to experience seamless links between the real and virtual worlds.

Another approach is the digital stories about the surrounding artworks (ArtLens project [8]) that use video, audio, text and image content for galleries. Or the photo galleries (2D and 3D) approach described by Masatoshi Arikawa Hideyuki Fujita, the projects created a spatial slideshow animation with personal Photo Collections and a map for storytelling

The games and quizzes based on mobile devices have been used for many years to facilitate the learning process and to make the museum visit more attractive, specially for younger pupils. Mineralia project presented by Guido Heumer, Frank Gommlich, Bernhard Jung, Andre Müller [33] is a pervasive search and quiz with the goal to enrich the experience of museum visitors. Players walk through the mineral museum and collect points by searching exhibits with as little as possible hints and by giving correct answers to questions about the respective exhibits. or ARCO project [9] that enables museum curators to build interactive learning scenarios, where visitors can gain information not only by browsing it, but also by answering series of questions presented in the form of a quiz. Or an interactive AR quiz based on Fishbourne Roman Palace [7], illustrated Figure 2.9.

2.3.3   Summary

In order to build interactive learning presentations on mobile devices involving diverse form of data presentation. Based on above literature, and requirements on the analysis phase described later, i attempt to implement an interactive quiz using digital documents (3D/2D graphics, text, audio, video) and their content is designed based on principle of exhibits. Users can access free application by downloading and interact with objects interactively either by using buttons, or touch screen.
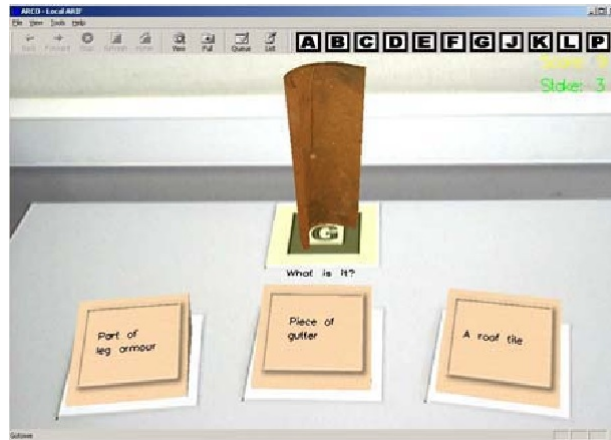
Figure 2.9: Example quiz scene.[7]

2.4 Visualization

So far, i explored navigation methods to locate locations, mapping methods to trigger digital content, effective digital contents. In this chapter, i will attempt to address the issue of visualization. By creating an interactive visualizations, we can allow visitors to explore our museum by seeing and interacting with artefacts content without distracting others.

2.4.1 Related Work

Nowadays, mixed reality (AR and VR) technology along with 3D graphics are the promising technologies for representing digital content and enhancing the visit. The advantage of this approach is that it does not demand too complex additional installations in the museum premises, and therefore qualifies as a both more discrete and less costly solution in terms of necessary museum infrastructure. From the museum point of view, the AR approach can provide a more intuitive and discrete way for interaction with the displayed objects, while for the AR scientific community, "museums provide contextually rich indoor environments for experimentations with AR applications, which as opposed with others, are open to a wide public, of different Information Technologies (IT) skills and backgrounds" [34].

Ian MacColl, Dave Millard, Cliff Randell, Anthony Steed [35] described a prototype of supporting synchronous co-visiting by physical and digital visitors, with digital access via World Wide Web or 3-dimensional graphics. The Lighthouse project [36] also mentions on presenting a study of a mixed reality system, which allows web, virtual reality and physical visitor to share a museum visit together. ARTLENS project [8] is an unique personal guide for museum visitors. The ARTLENS helps visitors to explore artworks

and create their own customized tour, illustrated Figure 2.10 and Figure2.11. Detecting visitor's location in the museum by indoor wayfinding technology and offer digital stories about the surrounding artworks. They also provide an augmented reality experience for user by using AR technology. In addition, users can use current tour map or create a map based on their favorite by themselves. The ARTLENS project also integrated digital signage content that mobile phone can get and display content from server.

VR visualization in the Victoria and Albert Museum in London Museum that the

Figure 2.10: "ARTLENS": The "Scan" function. [8]

Figure 2.11: "ARTLENS": The "Tours" function. [8]

objects can be visualized in form of 2D/3D Web pages as a virtual reality exhibitions, illustrated Figure 2.12. Or an AR visualization as in ARCO project [9], illustrated Figure 2.13.

2.4.2   Summary

In order to deal with interactive visualization that allows museum visitors to interact with the content in an more intuitive and exciting manner, i can design the system that support various visualization as Augmented reality (AR), virtual reality (VR), or Mixed Reality.
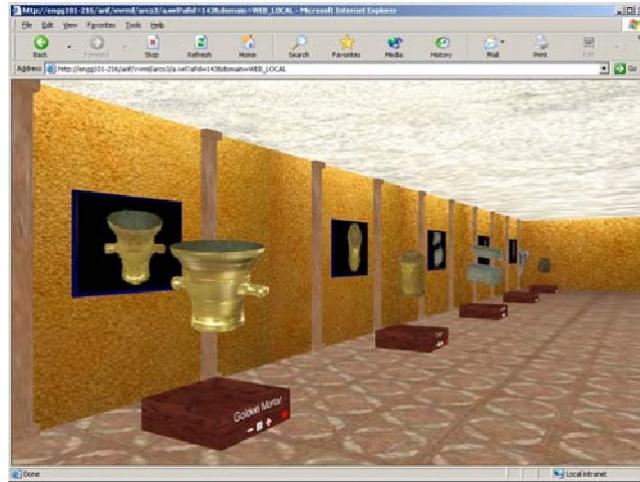
Figure 2.12: Example 3D virtual gallery. [9]
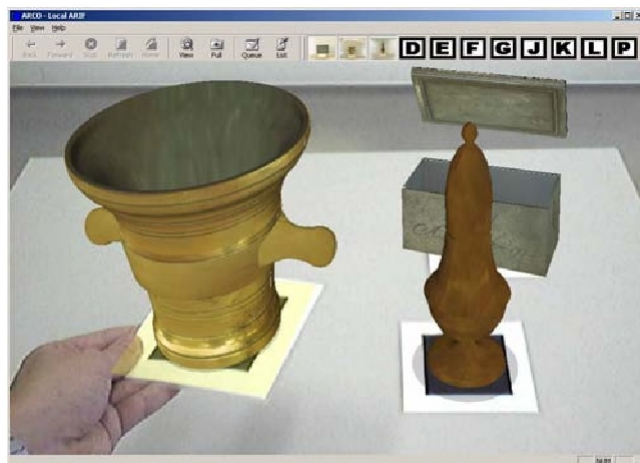
Figure 2.13: Example AR visualization. [9]

Chapter 3

Research Methodology

In order to try answer the research questions defined above, an interactive development based on user center design (UCD) was used as Figure 3.1. In the following, i will describe User Centred Design in more detail before explaining how i used this approach in my thesis.

3.1 User Centred Design

3.1.1 Defining User-Centered Design

The term 'user-centered design' originated from Donald Norman's research laboratory at the University of California San Diego (UCSD) in the 1980s and became widely used after the publication of a co-authored book entitled: User-Centered System Design: New Perspectives on Human-Computer Interaction (Norman Draper, 1986). Norman built further on the UCD concept in his seminal book The Psychology Of Everyday Things (POET) (Norman, 1988) [15].
User Centred Design is responsible for applying a user-centered approach in the project, this method focuses on end users and how they will interact or work with the software. "Great product ideas come from the marriage of a designer's detailed understanding of a customer's need and his or her in-depth understanding of the possibilities introduced by technology" [37] .In other words, user-centered design is cooperation between system developer and usability expert concentrating on users' need that provided by real end users during the entire design and development process incrementally. User-centered design aims to to create usable interactive systems, involving understanding, analysis, design, implementation, evaluation. and thus interaction is strongly user-centered and guarantees satisfaction of users.
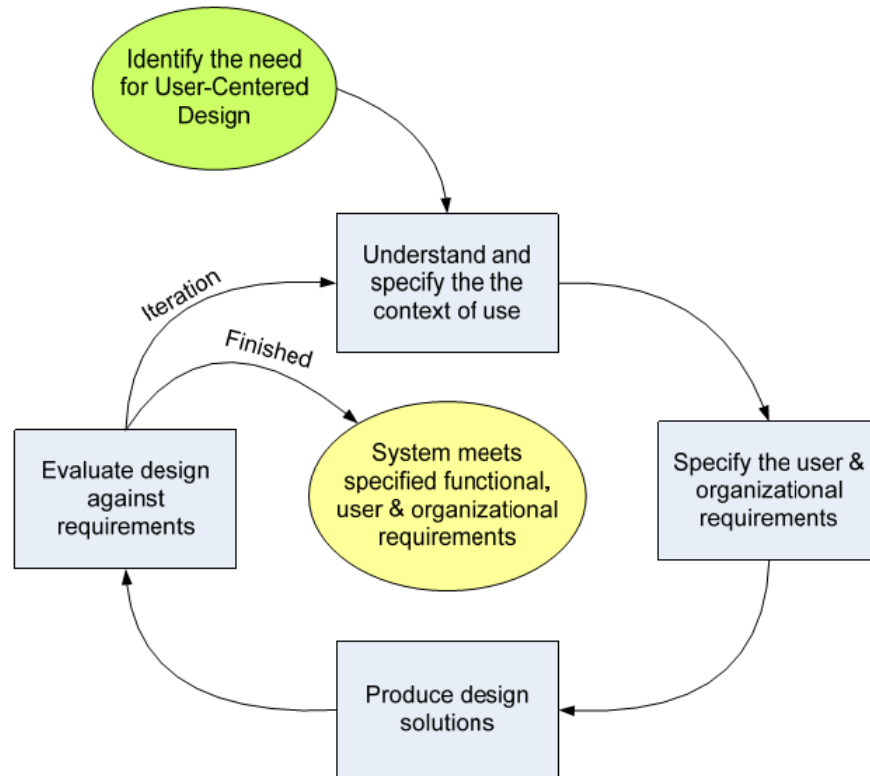
[38]

Figure 3.1: User Centred Design

ISO 13407 is a standard to describe how to conduct a user-centered design process (ISO-13407 1999). "Being based on the consensus of a wide international board of researchers and practitioners of the field gives it high credibility. Rather than describing different usability methods, it describes usability at a more abstract level of principles, planning and activities. Thus, it is more or less directed at those managing the processes. An additional important aspect is that it explicitly uses the standard definition of usability from ISO 9241-11 as a reference for usability " [38].

3.1.2 Context Of Use

In order to find out the requirements and identify the current issues, The following methods can be used in my project.

Interview: According to Plinio Thomaz Aquino Junior, Lucia Vilela Leite Filgueiras. (2005) [39], The best way to collect information about the user is by interviews focused on questions based on "what the users do", "what frustrates them", and, "what makes them satisfied".

Participant Observation: According to KM DeWalt, BR DeWalt. (2010) [**?**], Participant observation is the foundation of ethnographic research design and supports and complements other types of qualitative and quantitative data collection.

"By participant observation we mean that method in which the observer participates in the daily life of the people under study, either openly in the role of researcher or covertly in some disguised role, observing things that happen, listening to what is said, and questioning people, over some length of time" [40].

3.1.3   User Data Analysis

Plenty of both qualitative and quantitative data after conducting interviewing or observation. In this point, it is important to interpret the meanings behind this data and find the implications for the design requires careful and time-consuming examining. The data can be organized and classified in various ways such as significance, appropriateness or interestingness. Single user notes or answers on a single question of a survey can be interpreted and integrated into new notes with a slightly different purpose, for example representing user requirement. The quantitative data, if any, can be summarized and analyzed with mathematical methods.

The main goal if this phase is to find common rules and features within data collected. Results of this phase can be used for later phases as design phase or evaluation phase. According to Kaasinen, E. 2005 [41]"The emphasis of the design should be on deciding what are the targeted values to be provided to the end users and other stakeholders, and then focusing on designing and evaluating those values into the service."

In addition, the analysis can bring out new questions that need to be answered. "Beforehand built hypotheses may also be compared with the results. The new knowledge by interpretation helps not only in designing the product but also in aiming the product for right user group and use context. "[38]

In my thesis, i can use the following methods in order to analyse the data:

- Open Coding

- Consolidated Models

- List of Requirement

3.1.4   Designing

"Produce Design Solutions: Incorporate HCI knowledge (of visual design, interaction design, usability) into design solutions" [42]. Prototyping can be regarded as a method to serve the design. For this phase, i used storyboarding in order to design prototype in low level. They describe certain use situations and users' actions in general level, and provide requirements for what functionality the system should enable for the user.
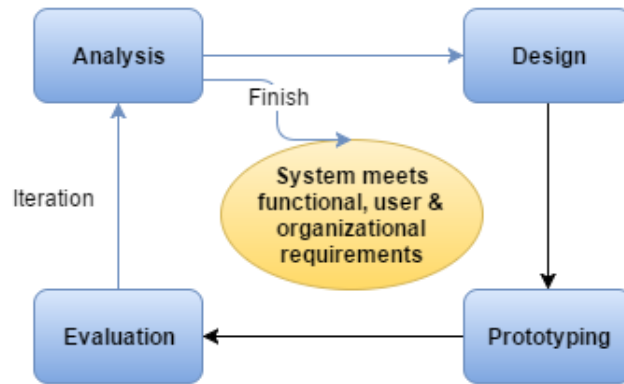
Figure 3.2: UCD for my thesis.

3.1.5 Evaluation

Prototyping created in early phase of the design is used to evaluate the feasibility of the overall design or in the later phases to evaluate details of the UI and functionality. "Evaluation methods have been adopted at any stage of the process for verifying the usability of incremental design stations, as well as of the final product" [43]. The main goals of evaluation are to assess the application functionality, to verify the effect of its interface on the user, and to identify any specific problem with the application, such as aspects which show unexpected effects when used in their intended context. In my thesis, i used observation and interview as the methods for evaluation.

3.2 User-Centered Design In My Project

In order to use the User Centred Design (UCD) in my thesis, i merged the first phase (Context Of Use) and second phase (User Data Analysis) into Analysis phase that is as Figure 3.2.

3.2.1 Chapter 4 - Analysis

In order to find out context of use, i conducted "Data Collection". Moreover, in order to analyze the data and generate requirements, i used Coding, Consolidated Models.

- Data Collection helps me to have a clear project focus that find out what problem intending to solve. Moreover, Interview and observe users as they work and inquires into the users' actions as they unfold to understand their motivations and strategy. The interviewer and user, through discussion, develop a shared interpretation of the work. It is like an active inquiry into the user's world.
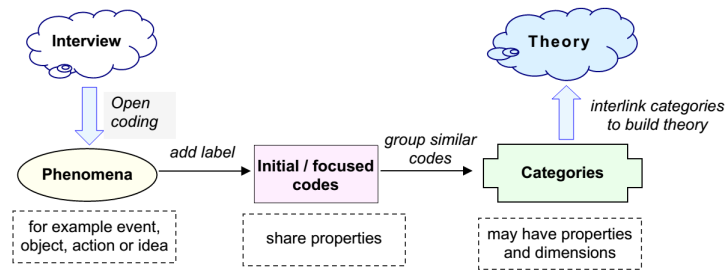
[44].

Figure 3.3: Coding steps in grounded theory (after Straus and Corbin, 1998)

.
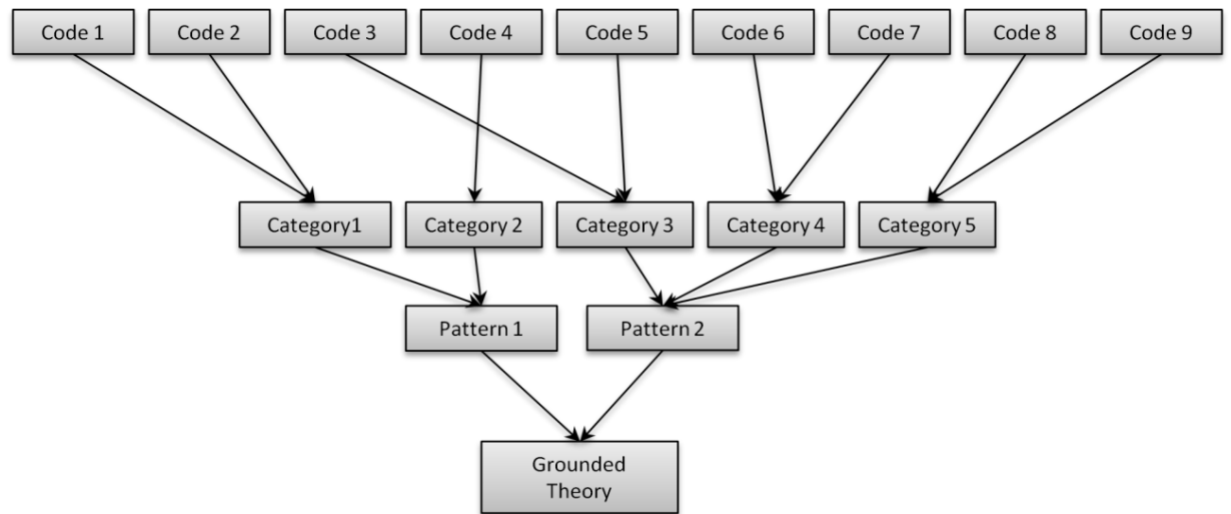
Figure 3.4: Workflow of Grounded Theory methodology

- In order to analyse data gathered from observation, and interview i used Grounded theory methodology that uses several coding techniques to examine interviewee's accounts at different levels. The general process of how to code an interview and develop a theory is depicted in simplified form in Figure 3.3.

    For my project, i chose Open Coding technique that is a process of analyzing textual content. Open Coding includes labeling concepts, defining and developing categories based on their properties and dimensions as Figure 3.4.

- These results were also displayed as an affinity diagram which was built to show the consistencies and conflicts within the user data.

- Finally, the results were summed up as the functional- and non-functional requirements, which were used as guidelines for developing the prototype later.
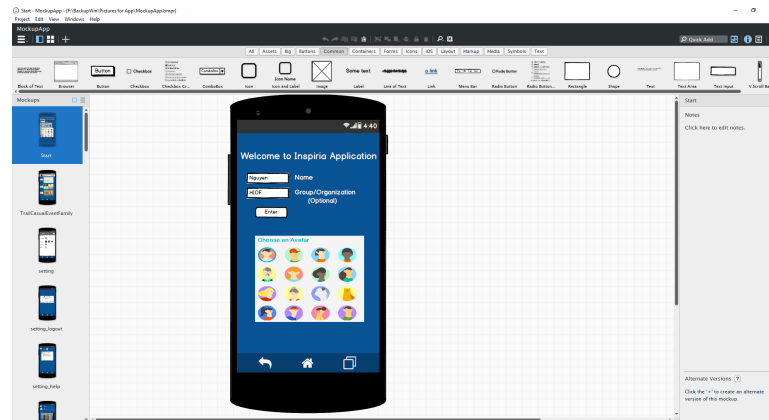
Figure 3.5: Mock-up Tools

3.2.2 Chapter 5 - Designing

This phase utilizes the consolidated data and requirements from Analysis phase in order to create solutions by means of technology. The ultimate goal is to create a totally new approach to perform the work. For my project, i used storyboarding for this phase. Storyboarding creates early visions of the required system that are explained to users in storyboard walkthroughs to get feedback on feasibility.

3.2.3 Chapter 6,7 - Prototyping

With the storyboards, now i am able to start building the prototyped system. Prototyping may occur on different levels of realism going from low to high-fidelity prototypes.

Low-fidelity let me focus on functionality, it was also the quickest way to get feedback on my design and content. From the feedback we made change quickly, and improved my initial designs.

In order to develop low-fidelity prototype, i created the wireframe, added more interactions and animation by using Balsamiq and Marvel software, as Figure 3.5. Then, the low-fidelity prototype would be tested by usability testing in the laboratory environment with users. The purpose of testing on the low-fidelity prototype is to reveal the biggest flaws and produce improvements before making High-fidelity prototype. High-fidelity prototype is mobile-based that provides more functionality and allows realistic (hand) user interactions.

3.2.4 Chapter 8,9 - Usability Testing, Findings

This phase is used to evaluate a product by testing it on users. I considered on how real users use the system and measured application's capacity to meet its intended purpose

in research question.

- Firstly, i hired candidates and divided them into 3 groups responding for 3 options (Casual Quiz, Event Quiz, Trail).

- Secondly, i gave one task for each group and left them freely to explore our museum.

- Thirdly, i observed visitors using app and conducted interview later.

- Lastly, i summed up the results, and evaluate Research Questions.

Chapter 4

Analysis

This chapter aims to understand as much as possible about users and their context that are needs, tasks, intents through extensive data collection. The analysis process consists of the following top-level steps: Data Collection, Open Coding, User Data Consolidation, Design Drivers.

- Data Collection was used to capture detailed information about how users interact with the artefacts in their normal work environment and requirements from Inspiria. This information was captured by both observations of user behavior and conversations with the user while she or he interacts and interview both the users and Inspiria staff to understand requirements.

- Code the data: In order to analyse the data collected from the observation and interview, i used Coding method to create user notes.

- User Data Consolidation: based on the notes, an affinity diagram was built to show the consistencies and conflicts within the user data. Consolidated Models also created to get a more solid and comprehensive insight into the data.

- Design Drivers: the final solid data was then sum up as design driver that will steer the new prototype design later.

4.1   Data Collection

In this project, i focused on the main research question described above that is "How can we make a mobile application which improves the conventional way of visiting the museum and encourages visitor participation both onsite and offsite of the museum

space?". The later observation and interview would be conducted with project focus on this issue.

4.1.1 Identifying System

In this project, I considered the available systems in Inspiria center, which would be the best context environment. Since Inspiria center is place where users come, experience and get information.

- INSPIRIA science center is a popular scientific recreation and learning environment for mathematics, science and technology where visitors can learn by experimenting themselves. In a Science Centre, children and adults can explore phenomena related to nature, environment, health and technology through activities on their own or in collaboration with others.

- For the previous work: There was a bachelor student group who worked on similar problem. They developed a quiz on websites that visitors could log in and answer available questions. Their prototype has basic functionality and is easy to interact with. However it has some usability issues such as adding new activities or combining with new technologies such as mixed reality and navigation.
  The website simply connect to database and get the questions, static images that are not interesting. Also, it can not be used for real activities such as making a event, navigation, trigger content, 3d visualisation.

- For the current work: The Kahood website is used. "Kahoot is a free game-based learning platform that makes it fun to learn – any subject, in any language, on any device, for all ages " [45].
  Kahoot is currently used for only event quiz that visitors come to a main stage, get the commond code and answer the question on the big screen. It is convenient and simple because visitor just need to go Kahoot side and answer the questions, but it is based on the design for website with drawbacks like previous work. For my work, i used this solution as a useful and valuable reference for me to implement a solution based on mobile devices.

4.1.2 Identifying Users

In this project, the system is planned to enhance interaction between users and the Inspiria center. The users can be visitors like pupils, students, teachers, business people, politician or the Inspiria's staffs. All of users can interact direct or indirect to my

application. For the design phase, the user data can be used to steer the design of new products/updating existing ones or give opinion for design phase and their own ideas that are implemented in the design. For the evaluation phase, users give information about users acceptance on the design. In other word, user knowledge serves as guidelines in design interaction and in designing future products.

4.1.3 Observation

By a combination of observation and video-recordingin the context of specific museum situations, it took a detailed look at visitors's 'natural' behaviour in our museum as Figure 4.1.

I mounted a movie camera equipped with single-exposure release high in one corner of the museum, concealed as much as possible from visitor's view. The resulting film, a series of snapshots of the entire room, provided a record of all activities in the museum, showing exactly:

- How many visitors entered the museum: It was impossible to count.

- Where visitors went and in what sequence: They liked to interacts to interact artefacts like weather forecast, jumping..

- How they could find the artefacts: They found artefacts by looking around or asked friends, inspiria staffs.

- How they interacted with the artefacts: They used hand, foot, and body to interact artefacts.

- How long they stayed at each artefact: had no exactly how long they stayed. They just left when they did not like it anymore.

- How long they stayed in the artefacts as a whole: had no exactly.

- How they stored information about the artefacts: They took pictures by mobile camera.

- How they go to the main stage: They found the main stage by looking the screen, go around or asked other as friends, inspiria staffs.

- How they played the event quiz at the main stage: They sat down around the main stage, and used mobile devices to access Kahoot page.

- Which problem are they having during visiting hours: Most of them told that they felt difficult to find information, and support

Figure 4.1: Visitors's 'natural' behaviour

4.1.4 Interview

In order to deeply understand the architecture and functionality of museum, i conducted in depth interviews with two operators (the educator and the head of Inspiria). Totally, four interviews were conducted, each of them took about three hours. Interviews are important part to requirement collection, because operators and users are the anticipate end user to the mobile app designed in my thesis work.

For the first interview, i concerned about the main problems that Kahoot webpage is lack of interaction and entertainment, also about observed issues of visitors. Based on the literature review, i suggested a alternative solution based on mobile devices with options of "Event Quiz", "Casual Quiz". "Trail".

For the second, third interview, and forth interview, i analysed and discuss requirements in more detail as following:

- What kind of application do you imagine ?.

- What is the idea behind the quiz ?

- Who will use the application?

- How should the people use the application? (scenario) ?.

- Where and when should people use the application?

- How does the current prototype function?

- What do you think about the current prototype?

- What works well?

- What is problematic?

- How do you think the current solution could be improved?

- What would be really fun to have? (new technology, content,.....)

- Why would it be fun? (motivation).

- What is the most important values for you? (expanded, robust, maintainability, secure, ...)

- How should the system be maintained? (who should be able to manage content)

Details of interview questions are shown in the Appendix A. In order to analyse the requirements from interviews, i used grounded theory which built categories and theories through the process of open coding that will be discussed in the next phase.

4.2   Process of Open Coding

According to the above methods, there are plenty of both qualitative and quantitative data, i need to cluster these data into meaning structures because "people act toward things based on the meaning those things have for them; and these meanings are derived from social interaction and modified through interpretation." [46]

- The first step, i went through the data(i.e. text) to break down into pieces to examine closely, compared for relations, similarities and dissimilarities. Different parts of the data were marked with appropriate labels or 'codes' to identify them for further analysis. I also wrote notes against a concept that i called "Memo" because a name with few words was not enough to describe an entire concept. A memo could contain a paragraph or even more if needed.

- The second step, i analyzed the codes to find the similarities and grouped them into categories based on their common properties.

4.2.1   Coding

For example:
Interview: What is the idea behind the quiz?.

Respondent: The idea is that people are more motivated to learn when there is an element of games and competition involved, rather than just walking randomly around pushing buttons and pulling levers. Almost all visitors have a smart phone. By using the screens they already have in their pockets, we have access to a brilliant, personal way of transferring information we want to give them. i want them to leave with the feeling of having learned something new.

AFTER

Interview: What is the idea behind the quiz?.

Respondent: The idea is that people are more motivated to learn when there is an element of games and competition involved, rather than just walking randomly around pushing buttons and pulling levers **["competition"]**, **[" revolution"]**,**["enjoying"]**, **["game"]**. Almost all visitors have a smart phone **["smart phone"]**. By using the screens they already have in their pockets, we have access to a brilliant, personal way of transferring information we want to give them **["transferring information"]**. We want them to leave with the feeling of having learned something new **["learning"]**.

4.2.2   Use of Open Coding

I used Open Coding for each interview. Open Coding is generally the initial stage of Qualitative Data Analysis. After completing each Coding, i did Axial Coding to build theories in an inductive process (i.e. Grounded Theory) based on codes.

- For the first interview, the coding helped me to find out a mobile application with three options, which are Event Quiz, Casual Quiz, and Trail, as Figure 4.2 and Figure 4.3.
  As figure above, the requirement for solution need to be a **competition**, **revolution**, **enjoying**, with **game** that i can group into **Entertainment** category. Also, it should take advantage of **smart phone** marked as **Technology** category. Moreover, the solution meets requirement of **Learning** and **Transfer Information** marked as **Education** category. Based on three categories (Entertainment, Technology and Education), i found out that the best solution is a **mobile application**.

- For the second interview, i conducted the second coding to get a detailed analyse of requirements as follows.

  - For the general application As Figure 4.5, it requires **robust**, **low failure rate**, **competition**, **flexible**, **new technology**, **for every ages**, **easy for visitors and admin**, **intuitive design**.

– For the Trail as Figure 4.4, It is an **infor trail** that visitors can follow on their **smartphones without competition**. The visitors can find **information** by themselves, and follow **a themed path** through our exhibition. The visitors can also **interact** the trail. It can be used for both **an outdoor** and **indoor** for visitors who come here to enjoy science park during closed/opened hours.

– For the Event Quiz as Figure 4.6, this option can used for **every ages**, **group or individual**. This option is controlled by **a host** from the stage in the middle of the centre, where visitors can **compete** against each other. The host gives visitor a **common code** to access the quiz. This option can **display the school/class** with the **highest score** per day/week/month/year and possibly reward the keenest pupils and teachers.

I grouped these codes into categories that host, common code, leader into **support** category and grouped competition, various ages, specific time, group/individual into **attribute** category, grouped scoreboard, winner into **Extra Infor** category. Finally, i grouped support, attribute, extra infor into **event quiz** category.

– For the casual quiz as Figure 4.7, the casual quiz is available **all days for casual visitors** of **all ages**, with the functions of **a winner announced each day**, and **a scoreboard** where visitors can see top list of scores. The visitors take the quiz as they **explore the centre**.

I also grouped these codes into categories that **No competition**, **individual/group**, **various ages**, **outdoor/indoor**, **various fields** into **attribute** category, also grouped **scoreboard**, **winnder** into **Extra Infor** category. Finally, i grouped **Attribute**, **Extra** infor into **casual quiz** category.

– For administration as Figure 4.8, the application must be **intuitive** and **easy to use** from both sides, user and admin. It should be **easy to change the content**, so that it's **flexible**, easy to **access the winners**.

• For later interviews, i also discussed in more detail requirements from the second interview and noted all codes, categories and theories on the wall called affinity diagram as Figure 4.9. This affinity diagram will help me to overview all of requirements and support me in drawing models that will be described in Consolidated Models phase.

4.3   User Data Consolidation

Consolidating will help to build a single, coherent view of customer's work practice. Consolidation brings together data from individual customer interviews so we can see
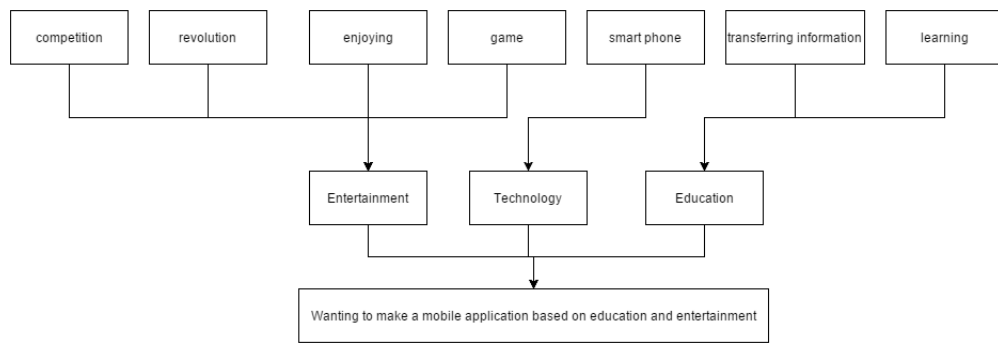
Figure 4.2: Use of Open Coding
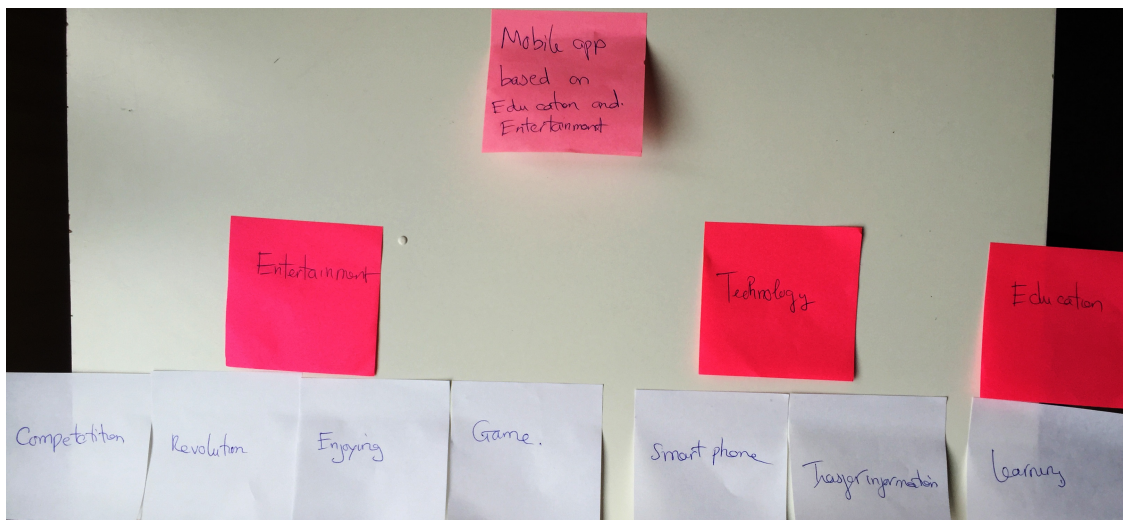
Figure 4.3: Use of Open Coding
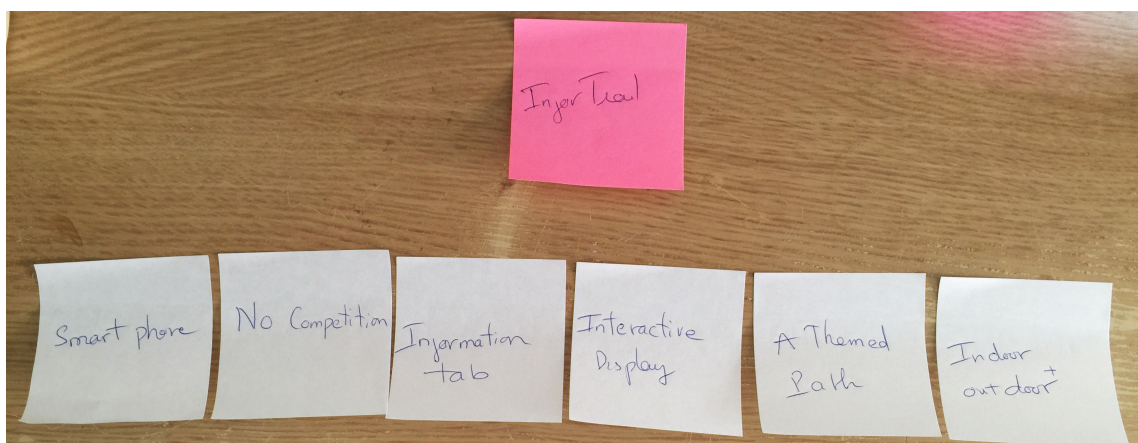
Figure 4.4: Requirements for Trail
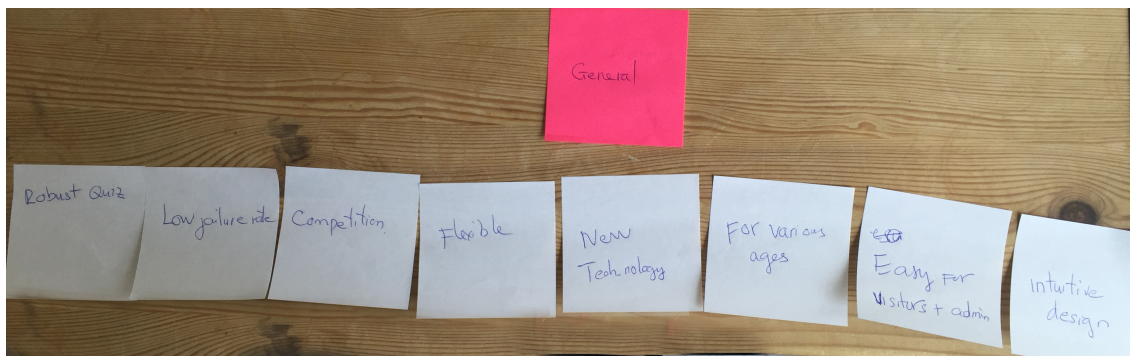
Figure 4.5: Requirements for general system
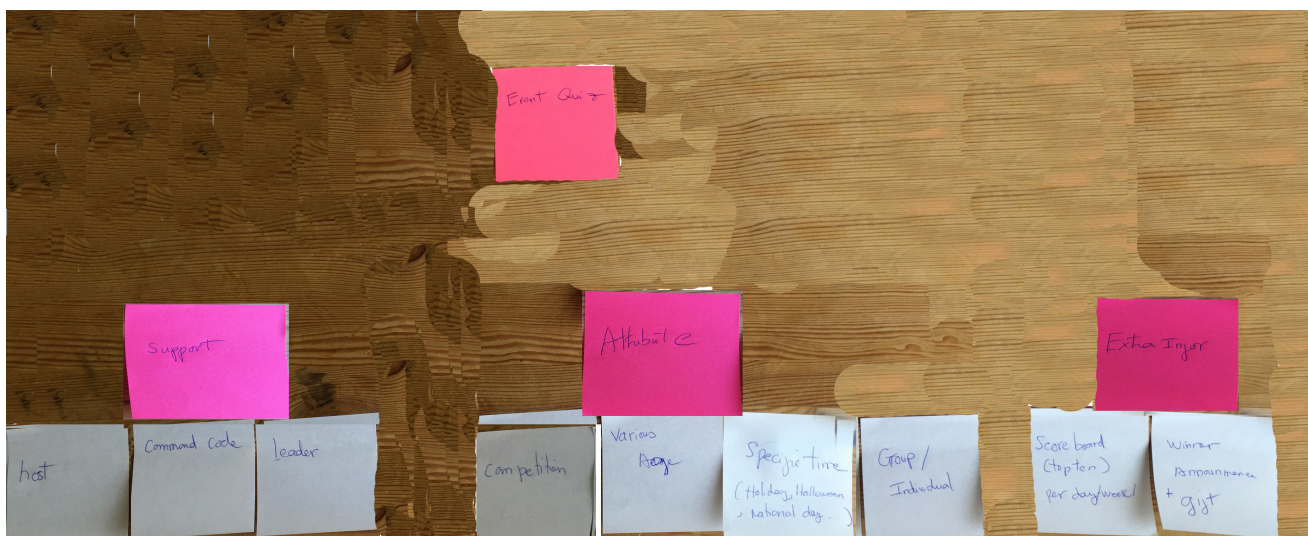
Figure 4.6: Requirements for Event Quiz
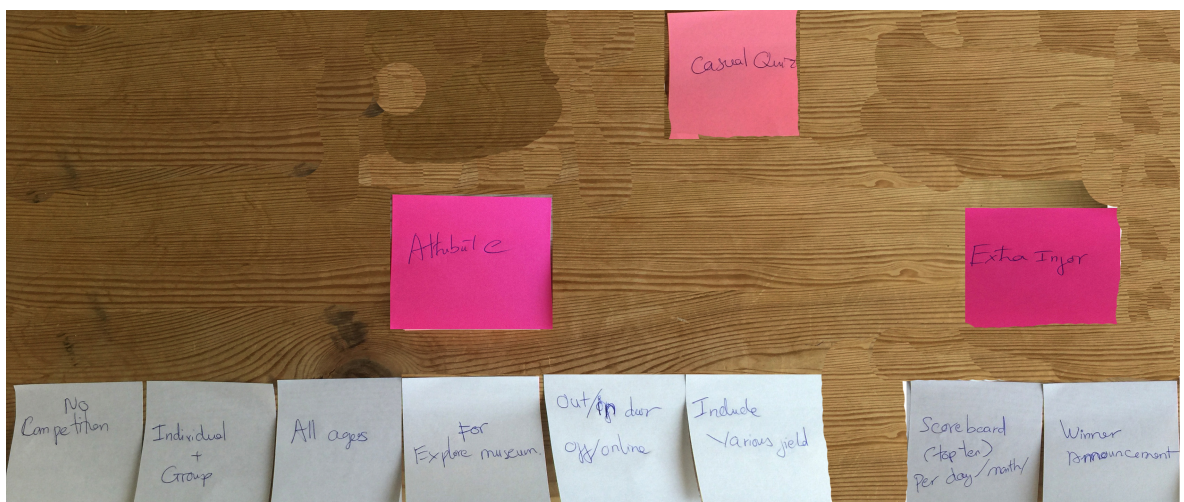
Figure 4.7: Requirements for Casual Quiz
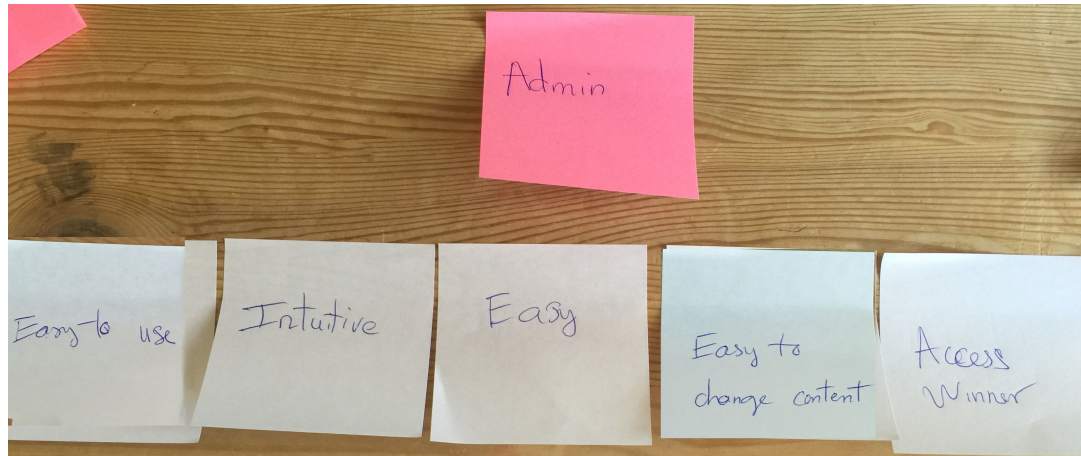
Figure 4.8: Requirements for Administration

common patterns and structure without losing individual variation. The two tools used for consolidation were affinity diagram and consolidation work models.

4.3.1 Affinity Diagram

Notes, categories and theories from coding session were used to create the coherent consolidation model and affinity diagram.
In the affinity building process, we sat down and went over the notes, categories and theories captured during coding phase. We aslo organized them into clusters on a wall. These clusters are named and summarized into higher-level issue. At the top of the hierarchy, it would cover the whole concern of all the issues. After complete affinity diagram, it could show the whole story of customer's work in a coherent way as Figure 4.9. This entire process is fully described by Holtzblatt in [47].

4.3.2 Consolidated Models

The consolidated models represent the sequences and interactions far better than the affinity diagram. Based on coding and affinity diagram results, consolidated sequence and interaction models were drawn. The models represented a superset of the group of individual models by generalizing them in a slightly higher abstraction level and including all the found problems in them.
In Contextual Design that is a user-centered design process developed by Hugh Beyer and Karen Holtzblatt [47] suggested to produce five consolidated model as follows:

- Consolidated Flow Model.

- Consolidated Cultural Model.
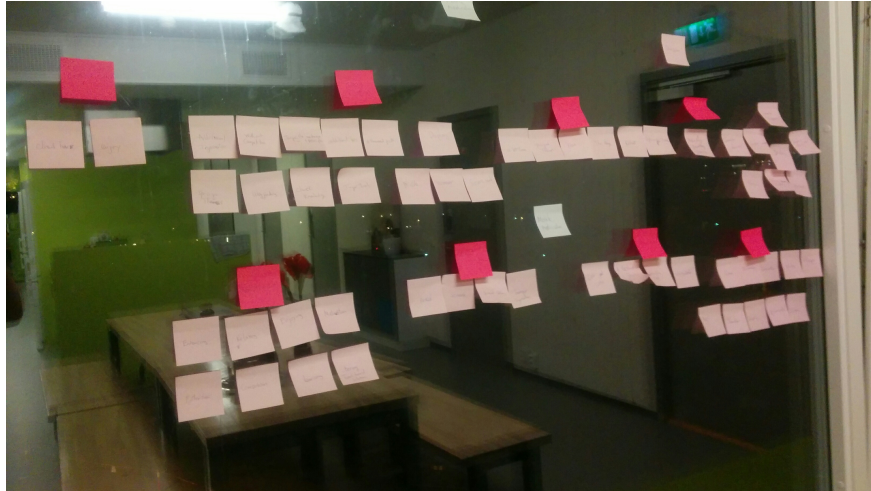
Figure 4.9: The affinity diagram brings together issues and insights across all customers into a wall-sized, hierarchical diagram to reveal the scope of the problem and the opportunities.

- Consolidated Sequence Model.

- Consolidated Physical Model.

- Consolidated Artifact Model.

However, in this project, i used Consolidated Culture Model that manifests the concrete influences among participants' expectations, policies, and value. I also used Consolidate flow model to find problem and requirements.

4.3.2.1   Consolidated Flow Model

As Figure 4.10, the flow model presents how visitor's roles are identified and how they participates are in a certain activity. The primary roles involved in the system include my application, the pupils, children, families, companies or politicians, host, administration, normal visitors. The arrows explicate the communication between participants, the problems in such interactions are represented as a red symbol.

What visitors mostly dislike is that they can be difficulty to interact with artefacts or read information based on text and pictures. Moreover, they need more support like saving information, more entertainment, remote interaction. The museum need a smarter way of providing information and interacting with visitors.

In order to address these problem, a mobile application was proposed which offers museum visitors an engaging experience as in Figure 4.10.
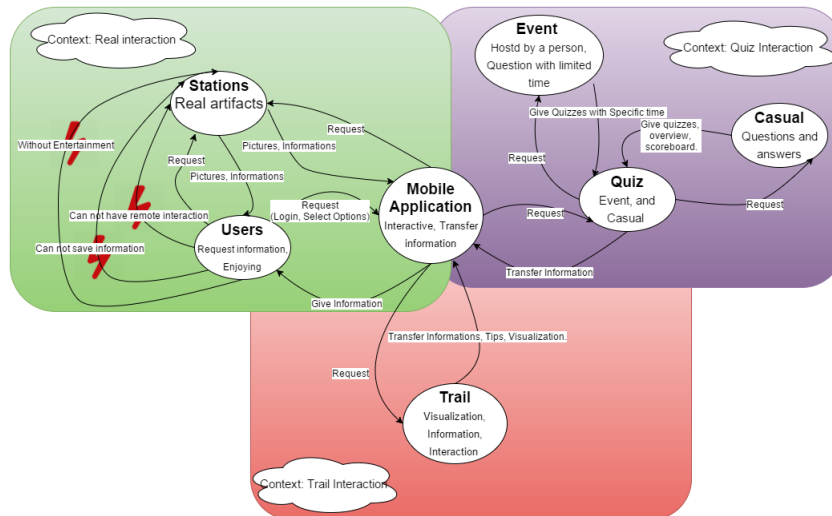
Figure 4.10: Consolidated Flow Model

- By using trail option, the visitors can take a tour in the museum or from anywhere with extra information like audio, video, images, text and other visualization like 3D for engaging interpretation.

- By using quizzes, the museum can increase the visitor's interest and involvement. The quiz was divided into Event and Casual Quiz as follows:

  - Event Quiz hosed by person will give visitors more challenging work for the limited time with rewards.

  - Casual quiz will allow visitors to access and play the quizzes that help them review knowledge from anywhere and anytime.

Moreover, the content can be modified by administration for special groups such as family, politicians or special event like national day.

4.3.2.2 Consolidated Cultural Model

As shown in Figure 4.11, the arrows represent the directions of influence and how pervasive each influence is. The consolidated cultural model shows how visitors culture clearly effects my application in our museum.

- Group 1: The adult, children, families, companies or politicians want to play a quiz (Casual or Event Quiz) to learn some thing. They also want to go around and explore our museum.
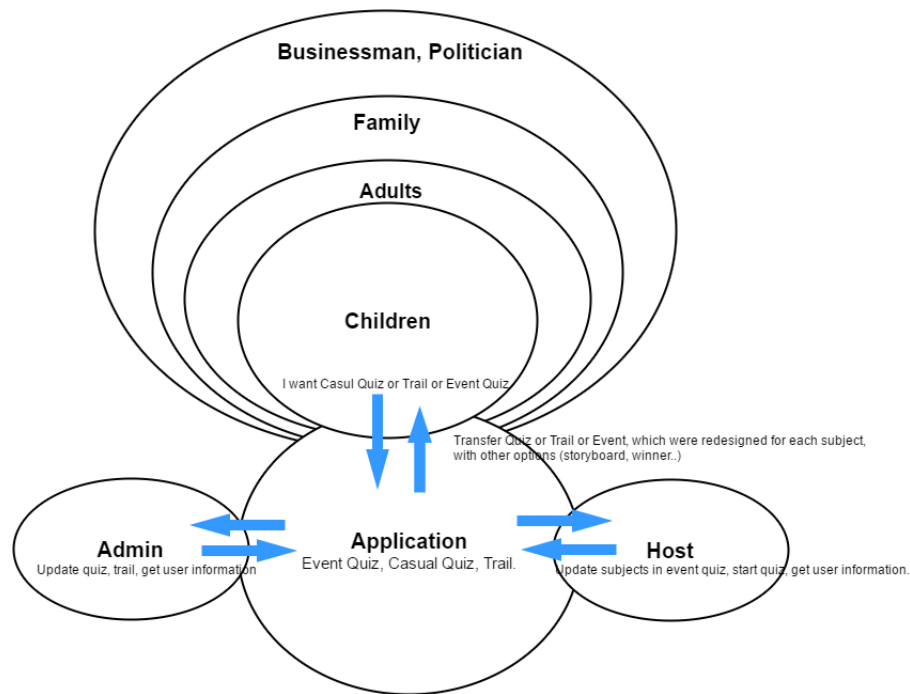
Figure 4.11: Consolidated Cultural Model

- Group 2: The administration want to manage my system as updating quizzes, artefact information, or getting user information. My system should give a interactive way to fulfill this requirement.

- Group 3: A host wants to update a special subject for event quiz, give a code for visitors to access event quiz, start event quiz and retrieve user information such as score, email to give a reward for winer afterwards.

4.4   Design Drivers

After interpretation and consolidation, the integrated affinity diagram and consolidated models were done. To sum these results up, design drivers were written. The design drivers would be served as guidelines, reference for evaluation when developing the prototype. The resulting drivers were grouped into functional requirement and non-functional requirement

4.4.1   Functional Requirement

- Registry would be a option when users access into system.

- Users must be able to log out of the system at any time

- The application must be able to cover two main areas, the "Quiz" and the "Trail".

- "Quiz" must be able to cover two options, which are "Casual" and "Event".

- "Casual Quiz" must be able to cover various categories such as "Healthy, Sport, ...".

- "Casual Quiz" must be able to display scoreboard.

- "Casual Quiz" must include the question and answer options under text, and illustration (pictures).

- "Casual Quiz" must include the review the answers at the end of the quiz.

- "Casual Quiz" must allow the visitors play this mode both outside and inside of museum.

- "Event Quiz" must include a countdown for each quiz.

- "Event Quiz" must include a "Game Pin" input (released by host for identifying each subject) that appear before accessing to quizzes.

- "Trail Option" must contain information of station under text and pictures or 3D.

- "Trail Option" must contain a trail of stations with interactive display that users can touch and rotate..

- "Trail Option" must contain information about nearest station and others.

- "Trail Option" must notify users when they at any station.

4.4.2 Non-Functional Requirement

Nonfunctional requirements provide guidelines on how to build my app correctly. Here are the general categories of nonfunctional requirements in the context of the app:

- Usability: This relates to how easily people can use my app. It should be easy for the users to install and use the application. Menus and functions should be clear, easy to find and either self-explanatory or well-documented. It should make end users become familiar with your app's functions, without training or help.

- Modifiability/Extensibility: The ability of the system to be easily changed to meet new requirements.

- Robustness: It must function in all conditions, always.

- Portability: The ease with which a system or component can be transferred from one environment to another.

- Flexibility: It must be easy to change the content. It also has ability of adapting the product to deal with different situations.

- Reliability: is the ability of a system to perform its required functions under stated conditions for a specific period of time. The failure in one section of the program does not affect on the entire system.

- Privacy: protecting personal information and undesired access to personal space. The user's personal data, logged data and other privacy sensitive information should be kept secure. When storing data on a system other than the mobile device, it should be made anonymous, i.e., removing all personal information from the data.

- Performance: This is essentially how fast my app works. It means that it takes to respond to a request for any service. It should be speed and throughput. To work properly, a response time of one second or less should be the minimum for the application to function properly

- Maintainability: Changing, adding and removing information and information sources should be facilitated. While users run the applications, it should be possible for the system administrator to make changes to the information base and make it available to the users afterwards.

Chapter 5

Designing

The application design is the most important part of the development process. It can help to resolve the problems, prevent future error appearing due to developers misunderstanding of project requirements. This chapter describes the design of the mobile application, which aims to meet the requirements of analysis chapter. It will not describe the design in detail, as this is discussed in the next chapters of low-fidelity prototype and high-fidelity prototype. The design is based on literature and Storyboarding collected from Østfold University students.

This chapter is divided into 2 sessions:

- Walking The Data: For creating storyboarding, a walk through of affinity diagram was conducted to capture key issues and create ideas.

- Storyboarding: After the "data walk" i ran a storyboarding session to invent how the system will streamline and transform the work users do by applying technology, which is fleshed out in more detail using pictures and text in a series of hand-drawn cells.

5.1 Walking The Data

The purpose of a data walk is to think about the data in details. The design ideas can pop up when walking on data. As a feature of User Interaction Design, it would be significant that users should be involved in this stage. Therefore, i recruited three Høgskolen i Østfold students to created ideas together. The first participant is 20 years old, female, and a Computer Science major. The second participant is 19, male, and a accounting major. The third is 22, male, and educational major. These three participants were chosen because they fit the criteria of being in my target audience by expressing

Figure 5.1: Walking The Data

an interest in socializing more. Moreover, they have flexible schedules and the desire to socialize. They all also have experience using mobile apps.

- To walk through the data, the first step is to read the affinity displaying on the wall that were notes coded from previous chapter.

- Later, the students looked into the consolidated models from previous chapter to build different dimensions of view on work.

- When each models discussed, student shared their opinions and many new design ideas were written down, the ideas were not restricted by any of the technological constraints.

5.2 Storyboarding

After doing data walking, each student was ready to create a vision of solution. The students used papers to sketch conversations about how to improve users's interaction by using mobile technology to transform the work practice in Inspiria.

Storyboards were then listed and evaluated to choose the best one. As a result, a consolidated vision of the new system will be created in following sections.

5.2.1 "Event Quiz"

In order to gather the visitors and encourage them attend a special event, we make event quiz option with prizes for team or individual as in the Figure 5.2.
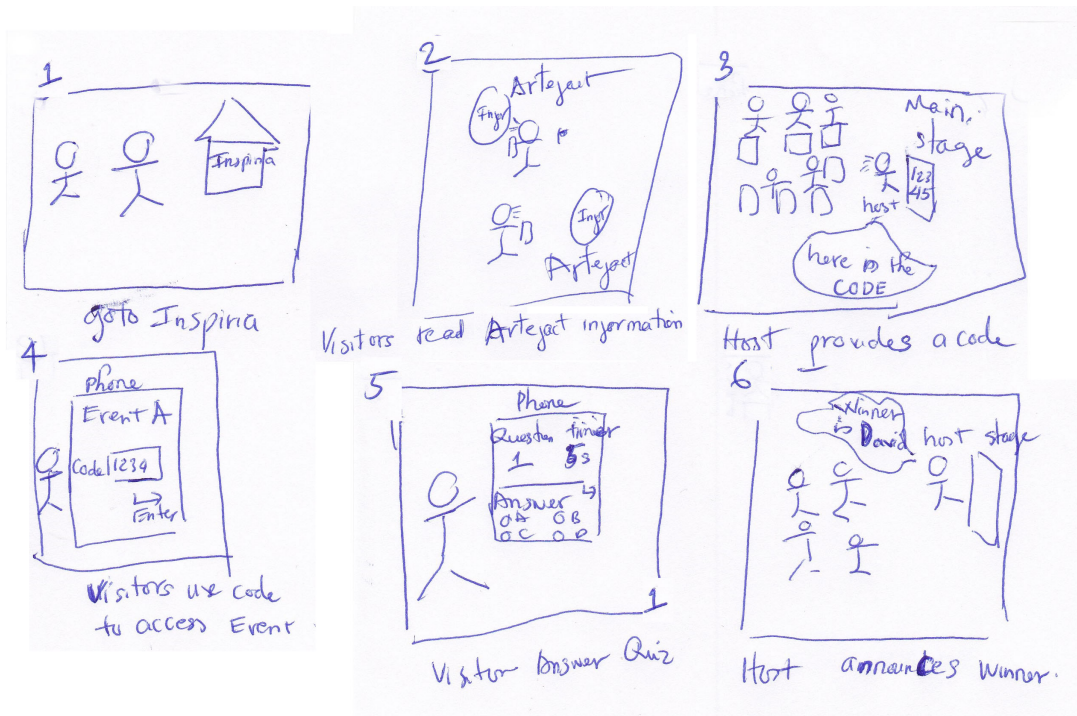
Figure 5.2: Event Quiz

- Firstly, the visitors are going to Inspiria as in **box 1**

- Secondly, they explored our museum as in **box 2**

- Thirdly, when a event come out, it will be notified by displaying on many screens. Visitors will use my app as a guide to go to the main stage. They then sit down on the chair front of the main stage as in **box 3**.

- Forth, a host standing on stage will introduce the event quiz, rules (Content, 5-second-limit for answering, a gift for winner) and give visitors a common code as in **box 4**.

- Fifth, the visitors use this code to access event quiz as in **box 5**. In addition, each question has 3 or 4 suggested answers, and only one of the answer is correct. The visitor has only 5 seconds for each question.

- Lastly, when the time's up and all of quizzes are answered, a score board and overview of the answers will be displayed on both user's mobile and big screen on stage. Then, host announces and gives a gift for the winner as in **box 6**.

In order to check requirements from design phase, we compared the outcome of story-boarding and initial requirements from coding as table 5.1.
Furthermore, we also reviewed cultural models as follows.

Initial Requirements	Outcome of Storyboarding
host	There is a host on the stage
common code	Code provided by host
leader	Leader can be a teacher who manage kids
competition	Visitors have to compete with others to get a gift
various ages	Kids, university students, businessman ... can use this application
special time	We can config for each special time such Halloween, National day.
group/individual	Group or individual can attend this option. They can play by themselves or cooperate with others to play
scoreboard	Scoreboard can be displayed at the end of the game,
winner announment	Host will notify the winner by using scoreboard.

Table 5.1: Check functional requirements for Event Quiz
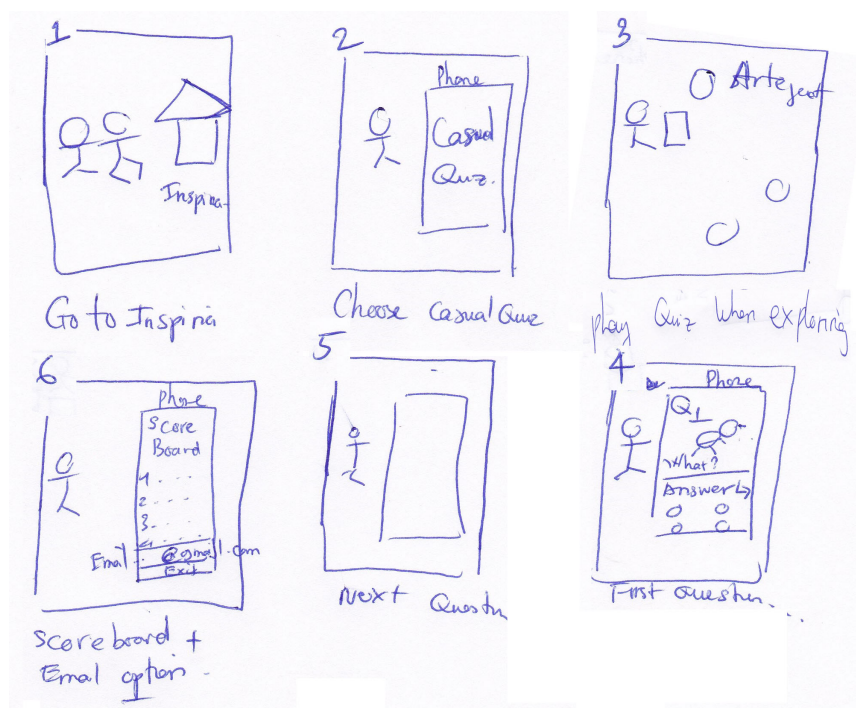
Figure 5.3: Casual Quiz

- For visitors, this option can increase the visitor's interest and involvement by getting them involve the competitive game. The pupils, children, families, companies or politicians can attend a event relating a special subject to learn or review their knowledge.

- For the host, he/she can update a special subject for event quiz, give a code for visitors to access event quiz, start event quiz and retrieve user information such as score, email to give a reward to visitor.

Initial Requirement	Outcome of Storyboarding
must be able to cover various categories such as "Healthy, Sport, ...".	The app meets this requirement
must be able to display scoreboard	The app meets this requirement
must include the question and answer options under text, and illustration(pictures)	The app meets this requirement
must include the review the answers at the end of the quiz	The app meets this requirement
must allow the visitors play this mode both outside and inside of museum.	The app meets this requirement

Table 5.2: Check functional requirements for Casual Quiz

5.2.2 "Casual Quiz"

In order to test visitor's knowledge of our museum, we created an Casual Quiz as the Figure 5.3.

- Firstly, the visitors are going to Inspiria as as **box 1**.

- Secondly, they want to test their knowledge, they can use a casual quiz which provides many categories related to artefacts as **box 2**.

- Thirdly, the visitors choose a category and play the quiz. In addition, each question has 3 or 4 suggested answers, and only one of the answer is correct. The visitor has only 5 seconds for each question as **box 4, 5**.

- Lastly, when the time's up and all of quizzes are answered, a score board and overview of the answers will be displayed on both user's mobile as **box6**.

In order to check requirements from design phase, we compared the outcome of storyboarding and initial requirements from coding as table 5.2.
Furthermore, we also reviewed cultural models that all of people like the pupils, children, families, companies or politicians can use the quiz to learn or review their knowledge.

5.2.3 "Trail"

We created a trail that is virtual tour for all users. It can provide detailed and up close images of museum artefacts and text descriptions or videos on a mobile device, sometimes with even more information than in the museum itself. Virtual tours also serve as an access option for disabled people who cannot otherwise experience exhibits due to physical, sensory or intellectual barriers. We also integrated navigation options,
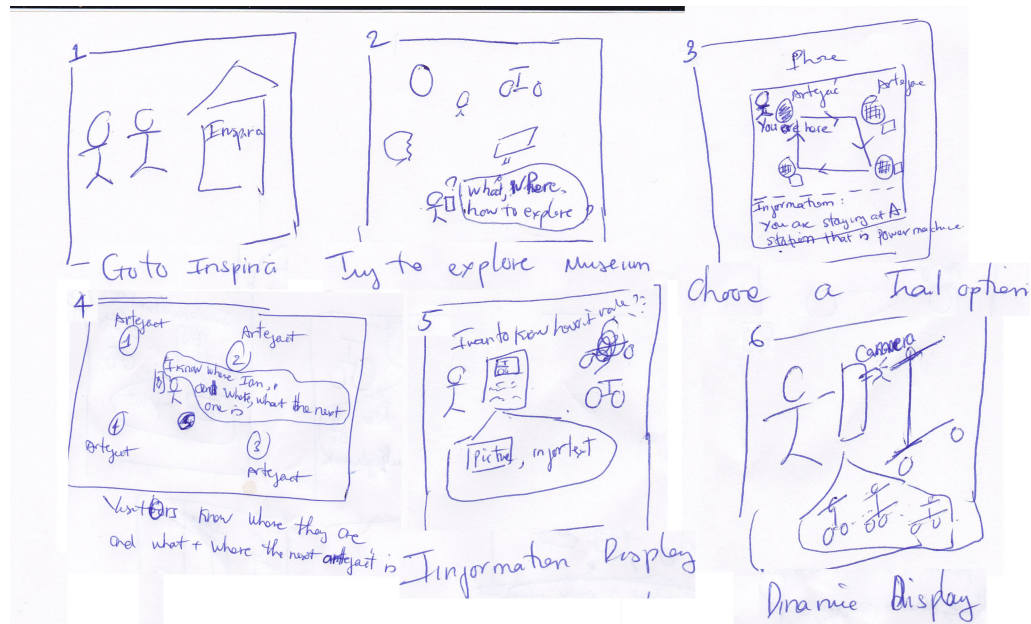
Figure 5.4: Trail Option

augmented reality view, all of which help to remove barriers between visitors and artefacts as the Figure 5.4.

- Firstly, the visitors are going to Inspiria as as **box 1**.

- Secondly, the visitors want to explore museum but they don't know what, where artefacts are. In order to address this problem, the visitors can choose a trail option as **box 2**, this trail can display a interactive trail including artefacts .

- Thirdly, the visitors now feel easy to explore the museum because they know where the nearby arteracts and others around them as **box 4**.

- Lastly, for more detail, the visitors can touch on the points on the trail which will show information related artefacts under pictures and texts as **box 5**. Especially, the AR option on the map can delivery more detail about arterfacts under 3d model as **box 6**.

In order to check requirements from design phase, we compared the outcome of storyboarding and initial requirements from coding as table 5.3.
Furthermore, we also reviewed cultural models that all of people like the pupils, children, families, companies or politicians can use the trail to learn some thing.

Initial Requirement	Outcome of Storyboarding
must contain information of station under text and pictures or 3D	The app meets this requirement
must contain a trail of stations with interactive display that userscan touch and rotate..	The app meets this requirement
must contain information about nearest station and others.	The app meets this requirement
must notify users when they at any station	The app meets this requirement

Table 5.3: Check functional requirements for Trail

Chapter 6

Low-Fidelity Prototype

In this chapter, i will describe a low-fidelity prototype based on storyboarding from previous phase. My low-fidelity prototype (Figure 7.1) consists of three main options. Trail option, casual quiz option and event quiz option. In order to simplify user experience and app complexity, i used an initial walk-through.
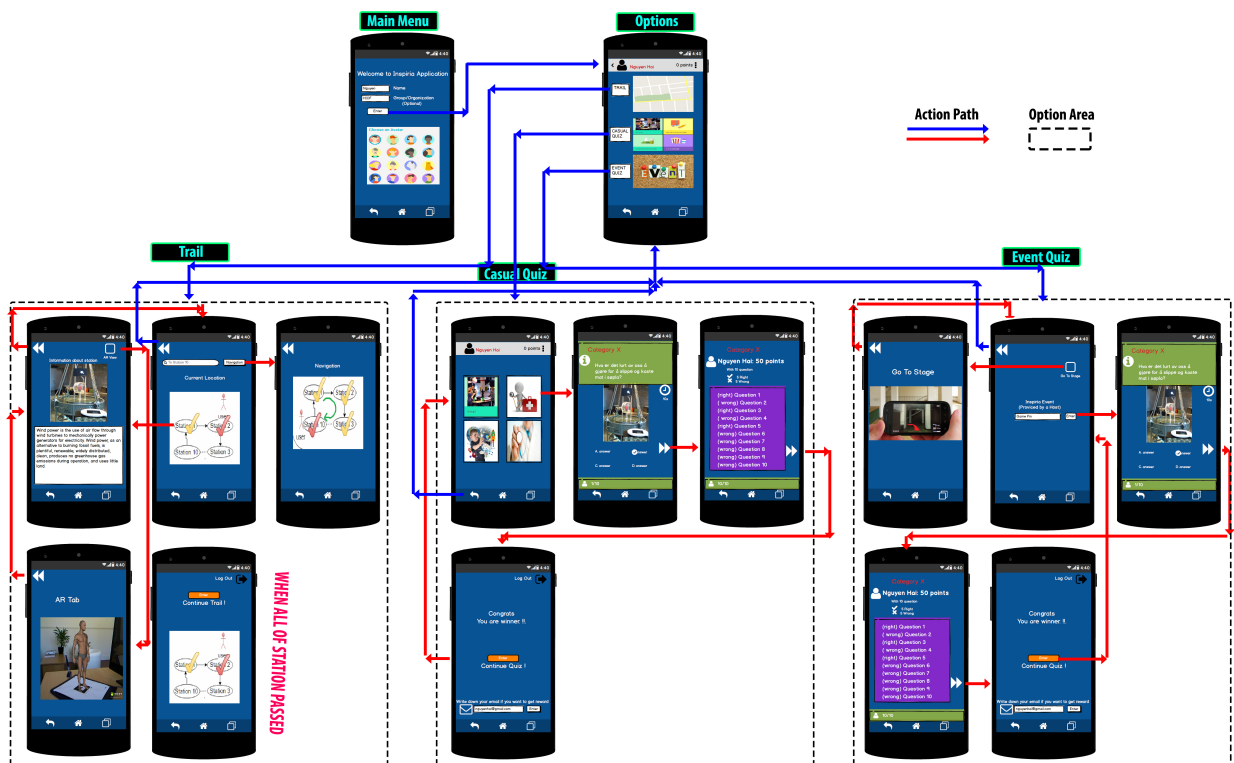
Figure 6.1: Over view
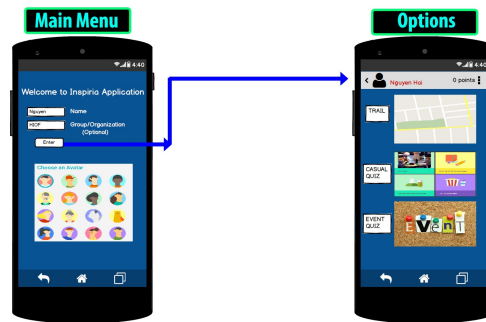
Figure 6.2: screen shots of the main menu.

6.1 Main Menu

The main menu is the first screen a player sees when starting the application (see Figure 6.2). The application do not require users to create an account, it lets the user input the name and organization (Optional) and choose a desired avatar. Pushing the "ENTER" button will start the application, and take users to the next screen. The application will not do anything until the user enter at least their name.

6.2 Games

(a) Casual Quiz   (b) Event Quiz
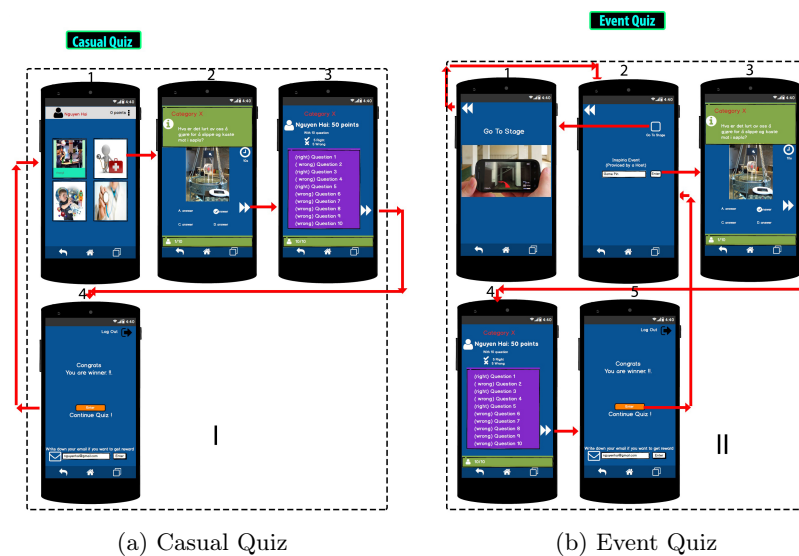
Figure 6.3: Quiz Game

A quiz game was developed to motivate visitors to come to our museum, also encourage to experience the stations. By taking quizzes, users can test their knowledge, compete against others to get award. A screen shot of the quiz game can be seen in Figure 6.3. The application consists of two concepts of quizzes, "Event quiz" where there is a host

standing on stage as screen shot 6.3a, and "Casual Quiz" where visitors can play by themselves as screen shot6.3b. Both two concepts of quiz have a time limit .

After starting the game, users can decide which concept of quiz (Event Quiz/ Casual Quiz) they want to play. The quiz gives users 5 seconds for each question (screen shot I,2 and II,3 in Figure 6.3). After 5 seconds, the next question will be displayed until last question.

After answering all the questions, the player will automatically see which ones he/she got right or wrong (screen shot I,3 and II,4 in Figure 6.3). Furthermore, user can know his/her current level and an email option to get award later as (screen shot I,4 and II,5 in Figure 6.3).

6.2.1   Event Quiz

This mode is active at a specific time as Figure 6.3b and is managed by a host.

Choosing the "Event Quiz" requires users to enter a code which was provided by the host (Screenshoot II,2, Figure 6.3b), the subject was set up by host (based on special time, days, seasons) as well. At the end of the game, there are a summary screen displaying right/wrong answer and ranking screen displaying order and an email box. The email help host to identify and give a reward if any visitor has the highest number of correct question (screen shot II,5 in Figure 6.3b).

6.2.2   Casual Quiz

This mode is always running, users can access and play the quiz whenever they want.

Choosing the "Casual Quiz" option gives users freely to choose their favourite subjects (screen shot I.1 in Figure 6.3a).

At the end of the game, there are also summary screen and ranking screen like event quiz. An email box will let sever identify and inform a reward later if visitor has the highest number of correct question per day/month (screen shot I,4 in Figure 6.3a).

6.3   Trail

The trail displaying our exhibition's floor plan allows visitors to have a more structured experience in the museum. They can walk through the museum with a available trail to explore our museum (screen shot 2 in Figure 6.4).

The trail displays all of stations (station 1, station 2...) as yellow and red circles. By looking at the trail, use can know the nearby station (red circle) and other stations

Figure 6.4: Trail

(yellow circles) as screen shot 2 in Figure 6.4.

By touching on any station on the trail, users can access to its interpretive media as pictures and texts (screen shot 1 in Figure 6.4), or 3d visualization (screen shot 4 in Figure 6.4) by pressing AR option and scanning an image targets on each station.

In order to make it easier to find a desired station, user can use "Search" function that requires user to enter a destination by tapping on the trail or typing on the text box as screen shot 2 in Figure 6.4. Later on, the application will display the shortest path from user location to destination station as screen shot 3 in Figure 6.4. Moreover, the application will display a notification of trail completion if user passes though all of stations on the trail as screen shot 5 in Figure 6.4.

6.4   Usability Testing

6.4.1   Purpose

The goal of this project step is to obtain rapid feedback and refine my design. I performed a simple usability test with my low-fi prototype. The test was designed to measure the problems and successes of the Inspiria application, primarily qualitatively. For this prototype i observed how the participants interacted trail, event and casual quiz tasks. I used Functional Requirements and Non-Functional Requirements to assess the testing that were User Interface design, usability of app that ability to be the ease of use, the ability to be the ease of leaning, the ability to change the content, ability of adapting the product to deal with different situations, challenging with other. Also i collected comments, problems that users made about the app as they worked through the assigned tasks.

6.4.2   User Profile

For the lo-fi prototyping experiments, i observed five Høgskolen i Østfold students interact with my prototype. The first student is 18 years old, female, and a business major. The second student is 21, male, and a computer science major. The third, forth student is 22, male, and accounting major. The fifth student is 20, female, and computer science major. These five students were chosen because they fit the criteria of being in my target audience by expressing an interest in socializing more. Being college age, they represent a significant portion of my expected consumer base because they have flexible schedules and the desire to socialize. They all have experience using mobile apps but were also unfamiliar with Inspiria App.

6.4.3   Test Environment And Equipment Requirement

Before the evaluation, i set up a laboratory environment, in which there were artefacts (fake machines with instruction), a stage with host, image Targets sticking both on the stations and on the floor. The phones used for the testing were 2 NEXUS 5. All of the phones ran on the Android operating system and will be equipped with SIM-cards. The SIM-cards were needed in order to access the Internet.
In order to interact with prototype, i firstly gave my phone to student that installed my prototype on Marvel application. The students could interact directly on their mobile phone as Figure 6.5. The environments were kept as relaxed and casual as possible to prevent the tests from feeling stuffy or intimidating, which has the potential to limit

the honesty of the subjects' responses. This allowed me to get more accurate feedback because this gave them the chance to take their time to give feedback and ask helpful questions.

6.4.4 Test Monitor Role

The students were asked to reply on the application, its functions and their own abilities to perform the required tasks. I just intervened when the students appeared to be completely stuck. I also encouraged the students to share their thoughts and doubts while carrying out the tasks, in accordance with the "Think loud" protocol. Also, i prompted the students for their thoughts when they appeared to be in doubt.

For the interview: i printed out the questions and invite 5 students to take interviews. I conducted open interview with a free discussion with students. At the same time, i took the notes and recorded the answers from students

6.4.5 Methodology

Before the beginning of experimentation all students had been contacted by private SMS. I explained to them that is a part of a master thesis and that the results would be used in a research. Moreover, an explanation of how the app will work and its basic function were given to everybody that were easier for them during the test. i also answered question from students prior to them trying the app.

6.4.5.1 Task

The students were given 3 tasks during the test in order to make up an impression of the application.

- Casual Quiz: The first task that each student was asked to play the casual quiz that help them check their knowledge about museum. In order to answer the question, the students were suggested to go around artefacts and read small instruction that provided knowledge about artefacts. After that, each student is supposed to choose a category which generates event suggestions based on the student's interests and schedule. Having 5 seconds for each question with total 5 questions/ 1 category.

- Event Quiz: The second task that each student was asked to play the casual quiz. Before playing the quiz, each student was asked to use "AR View" on the main screen and point camera to images targets on the floor to find the main stage. From

there, they got the code from me (as a host) and enter this code to Code option to enable event quiz. Having 5 seconds for each question with total 5 questions/ 1 time.

- Trail:The second task that each student was asked to follow a trail to explore our museum. In order to find information related to artefacts, i asked the students to press on red circle or green circles, which were nearby and faraway artefacts. Also, each student was asked to use "AR View" on the main screen and point camera to images targets beside of each artefact to view 3d models.

6.4.5.2 Observation

I used observation method to investigate how well prototype supports them. Observation were conducted through all the three tasks above. While students were using application freely, i moved into background watching their interaction and movement. I looked for general use, technical problems, navigation and other issues connected to requirements. In order to store information, i created a video footage and notes by camera and papers.

6.4.5.3 Interview

After using the app, i conducted individual interviews with these students in order to observe usability of application. Five students were asked to sit down on the chair and answered usability testing questions. The students talked out loud as they went through the tasks which gave me insight into what was good or bad about my prototype.

- Question 1: How was your user experience of this app in general (was it ok? Was it anything annoying with it? Did you have a good or bad experience with it?)?
  Two students said that they felt good about the application, one had normal experience (Not good, and not bad).
  One student said that she especially impressed about the trail in Trail Option because he could use it as the virtual guide right on her phone without guiders. Also, he found out it is easy to find a interesting artefact by touching on the trail. Information tab gave enough information with various methods of displaying information.
  The last one said that he really impressed AR technology that is very useful for him to go to the event stage.

- Question 2: Is it easy to understand what this app is for?
  All of students said that it was easy to understand what the app was for. But they all agreed that it should have a introduction tab before accessing application.

- Question 3: Is it easy for you to understand which buttons to push to get to where you want to go?.
  One said that the navigation options should be more clear and make it as simple as possible, he gave ideas that show a hint for each button.
  But one of them said that the application need to add a help tab that helps users who are not familiar to technology.
  Others said that they can understand how to use these buttons.

- Question 4: Is there anything with this app that is hard for you to understand ?
  Two students said that they did not understand what is "AR View" about.
  One student asked about how they can get reward, he though that the application should give more instruction before user accesses the application. Another student had the same idea that it is little difficulty to understand all functions without help. Others said that they clearly understood.

- Question 5: Is there anything with this app that you feel is unnecessary or superfluous?
  Four students said that they did not feel that there was anything unnecessary with the app. There was a student said that the "Profile" option was unnecessary.

- Question 6: Is there anything, which is not represented in this app that you wish would be in it?
  One student said that the application should send information to users via email option, each artefact should have rating tab.
  One students said that information tab in Trail Option should display images, videos, text and links to further reading, not only image and text.
  Another student said that application should have hints at buttons or more instruction text, and app should have information image in event quiz option.

- Question 7: How do you generally feel about the design of this app (was it ok? Was it anything annoying with it? Did you have a good or bad experience with it?)?
  Three students said that the design was fine, one student said that application was not too impression and design should be improved.
  the last student said that the design is a bit complex and look old.

- Question 8: Is everything easy to see (for example the buttons)?
  All of student said that setting, button and icon, avata .. were easy to see.

- Question 9: Do you feel the colors used fit this app?
  Tree student said that the colours were fine, one student said that the colours were simple and not too impression. The last one felt that the colours were bit strong.
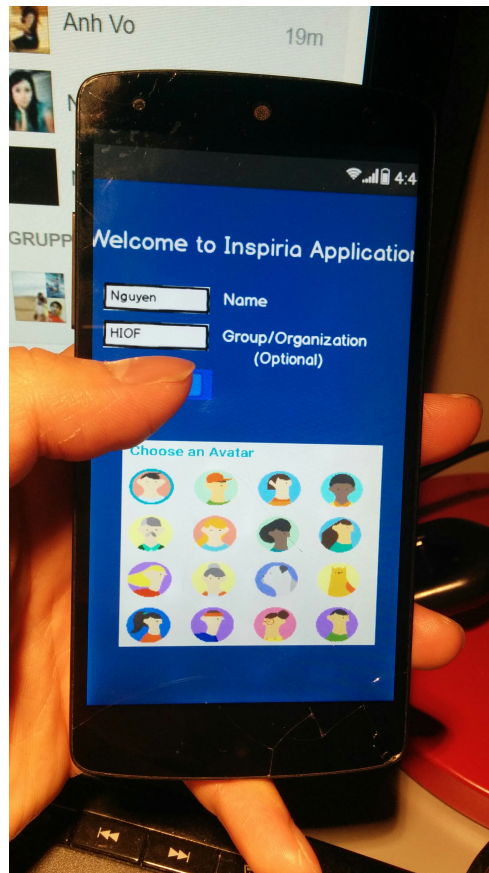
Figure 6.5: Low-fidelity prototype after transferring to Marvel application

- Question 10: Is there anything with this design that you feel is unnecessary or superfluous?
  All of students said that the application were generally fine.

- Question 11: Is there anything, which is not represented in the design that you wish that was there (colors, placements, buttons, information etc.)
  Four student had no comment, one student said that should add the Inspiria Logo on log on the main page.

- Question 12: Have you learned some thing after use ?
  All of students said that they got something about artefacts.

6.4.6 Findings

After conducting a evaluation on my Low-fidelity prototype, good feedback was retrieved from the students. The findings in this section were used to improve and further develop the mobile application. The results include engagement and motivation, technology, learning, information presentation, usability.

- Engagement and motivation: When observing the students throughout tasks was that almost all students were really engaged while using the system. Even though the prototype was just low-fidelity on mobile phone. The results of interview reveled that they were motivated by new technology as Augmented Reality, or Navigation.

- Technology: The technologies like Augmented Reality and Navigation included in the mobile app seemed to have a very positive effect on the students attitude towards the interaction with museum.

  They scanned the image targets on the floor and they all seemed pretty amazed, and spent time to look at the 3D models. All of students told me that they have never seen the AR technology before.

  I observed that most of students liked to see 3D information provided by AR than text or images provided by touching on the trail. For the event and casual quiz, they were quite excited but some of them seemed not interested also told me that the concept are not too special.

  Furthermore, interview revealed that some of students did not understand what "AR View" was about because it was new for them. They needed more information for each new technology.

- Learning: Although the learning outcome of using the system is hard to say much about because short period of time and small number of student, the results from the interview and observation revealed that the students themselves think they are learning. This fact at least has the potential to motivate the students to learn while using the system.

  The fact that the student actually tried to memorize the information provided by trail in order to answer the quiz from event quiz and casual quiz, this observation was the same as answers in interview session.

- Information Presentation: The students seemed to be satisfied with the way all the information was presented. Using visual graphics to present the information to the students was a very popular solution. Each students easily found their favorite artefact, and quickly saw how the artefact work. It was easy and mobility to play a casual quiz and event quiz.

  However, some of them need information under videos not only image and text or 3D because they want to hear some thing like instructions. Another student said that application should have hints or tips because they have difficulty with new technology and new interface without instructions.

- Usability: The results from interview and observation revealed that the majority of students found the system easy to use. Although some complained about strong color, confused button, Inspia logo for event quiz, old style or unnecessary "Profile"

option. Moreover, they also wanted to have a way to save information like email, a way to rate each artefact as well. For the design.

Chapter 7

High-Fidelity Prototype

After conducting a usability test on my Low-fidelity prototype, i got feedback and findings from users. In this chapter i will use this useful information to redesigned my low-fidelity prototype and generate high-fidelity prototype based on technologies from literature review.

(a) An overview of Mobile-platform

(b) An overview of Website-platform
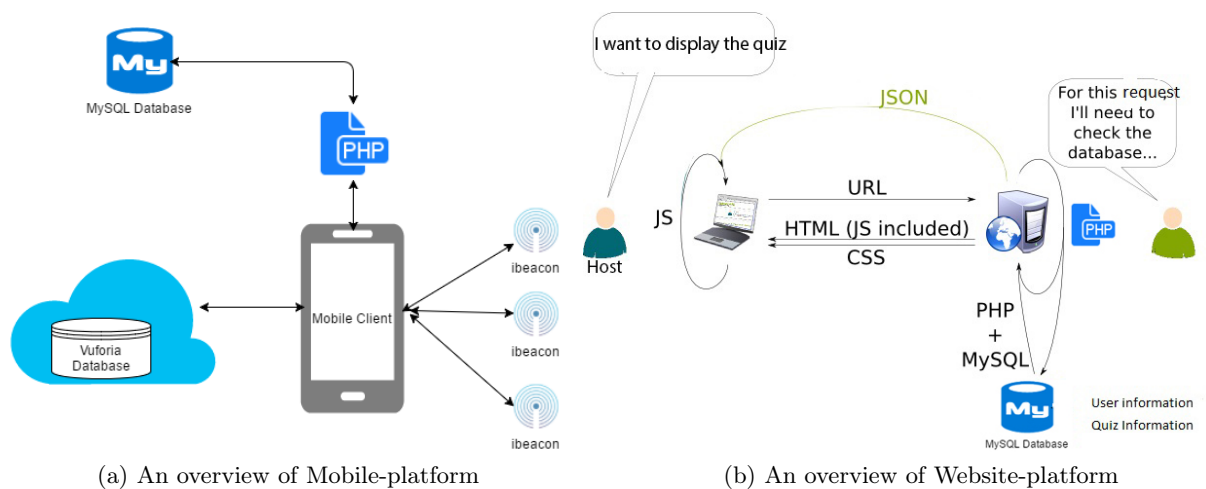
Figure 7.1: An overview of my system

The system is implemented on 2 platform that as follows:

- Mobile-platform: This system was integrated a MySQL database, and the Vuforia imagetargets database and ibeacon devices. The overview of how the different components of the system was connected can be seen in Figure 7.1a.

- Website-platform: This system is new ideas based on my observation on visitors when they were using event quiz. I want to combine the solution of Kahoot site and our mobile application for the event quiz. The website was designed based on

Figure 7.2: User and Quiz information

MySQL database, Javascript, PHP, HTML and CSS. It is used for displaying quiz, scoreboard as Figure 7.1b.

Firstly, i will describe technical description with 3 main group elements as follows:

- Common Elements:

  - MySQL database:

  - PHP scripts:

- Mobile-platform Elements:

  - Ibeacon and Indoor Location:

  - Vuforia and Augmented Reality:

  - Google Cloud Messaging:

- Website-platform Elements: HTML, CSS, Javascript

Secondly, i will describe the user interface of my application for both Mobile-platform and Website-platform.

7.1 Technical Description

7.1.1 Common

7.1.1.1 MySQL Database

I created a database with a free webhost (000webhost) with available phpMyAdmin tool. I used this database for storing the questions for quiz, artefact information, the user information. Moreover, I used phpMyAdmin to create User Table and Quiz Table that are to store user and Quiz information as Figure 7.2

7.1.1.2 PHP scripts

I used PHP scripts for fetching, updating, and inserting data from mobile application and Website. The PHP files contains various files and each files contain PHP language script to access the MySQL database and transfer the data between the receivers, Such as:

- db_config.php: will have database connection variables

- db_connect.php: to connect to database

- create_product.php: to create a new user information in user table.

- get_all_products.php: To get a json to list all the question on android device by taking product id (pid) as post parameter.

- update_product.php: To update question details. Each question is identified by pid.

7.1.2 Mobile-platform

7.1.2.1 Ibeacon and Indoor Location

"iBeacon is an extension to the location service offered by Apple in its devices. It allows iPhone applications to become location-aware. iBeacon is based on Bluetooth Low Energy (BLE) and provides a proximity location service for an indoor environment" [48].

In my thesis, i used this technology as a contextual interactive guide, which is a trail. Ibeacon helps to track the visitor's location, allows the guide to highlight the floor the visitors're on, show where the closest to special arterfact is, and recommend artefacts which are nearby and relevant for them. Moreover, the reason for using this technology is that it has some decisive advantages in buildings which have no permanently installed WiFi infrastructure and determine the position with an accuracy of up to one meter. It is also easy and very flexible to install ibeacons for indoor navigation.

Each beacon is identified by three values:

- UUID, most commonly represented as a string, e.g. "B9407F30-F5F8-466E-AFF9-25556B57FE6D",

- Major number, an unsigned short integer, i.e., an integer ranging from 1 to 65535, (0 is a reserved value)

- Minor number, also an unsigned short integer, like the major number.

Because of limited time, i just implemented a indoor map and make a ranging beacons that actively scans for any nearby beacons and delivers results to my application every second.

In order to implement this function, i used software and hardware as follow:

- iBeacon devices produced by Estimote was used to identify location and measure distance.

- Estimote SDK was used to communicate my application and iBeacon devices that received signal from iBeacon and simulate on my application.

- SVGMapView library was used to make a trail based on signal from iBeacon and Estimote SDK.

The detailed process is described as follow:

- 1. I placed a single iBeacon to each artefact in our museum as Figure 7.3.

- 2. To "draw" the museum, i used SVGMapView library and a svg file to create a visual map as Figure 7.4.

- 3. I used Estimote SDK for ranging beacons that will get a full list of matching beacons currently in range—complete with their UUID, major, and minor values. Each beacon broadcasts its Bluetooth signal with a certain strength-a strength which diminishes as the signal travels through the air. This enables the receiver device to make a rough estimation of how far the beacon is. Strong signal = it's close. Weak signal = it's further away.
  As in the Figure 7.5, BeaconManager class takes a role of managing ranging iBeacons that will display a list of iBeacons based their distances.

- 4. Based on above list from BeaconManager, i used Estimote UUID, major, and minor values of ranged beacons to determine exactly which beacons are likely closer, and which are probably further away from the device as Figure 7.6.
  Also, I categorized the beacons into four proximity zones:

  - Immediate (strong signal; usually up to a few centimeters)
  - Near (medium signal; usually up to a few meters)
  - Far (weak signal; more than a few meters)
  - Unknown ("hard to say", usually when the signal is very, very weak)
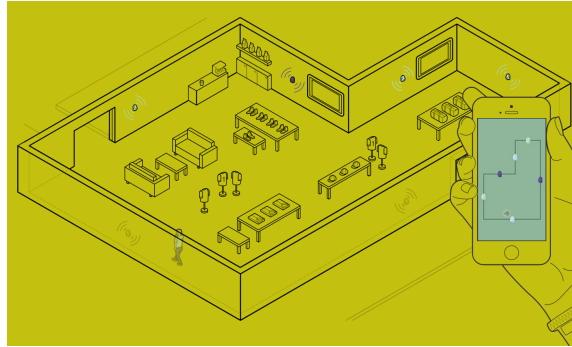
Figure 7.3: Place iBeacon to each artefact [10]
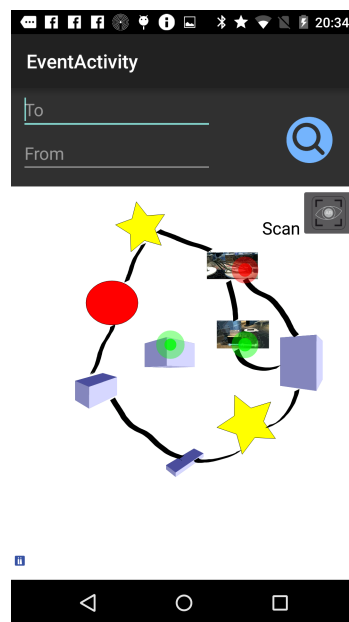
Figure 7.4: Inspiria Indoor Map

```
beaconManager = new BeaconManager(this);
beaconManager.setRangingListener(new BeaconManager.RangingListener() {
    @Override
    public void onBeaconsDiscovered(Region region, List<Beacon> list) {
        {
            if (!list.isEmpty()) {
                Beacon nearestBeacon = list.get(0);
```

Figure 7.5: Estimote SDK

- 5. I created list of attractive places and marked them with color circles in virtual map that make visitors easy to know which the artefact is the closest (red color) and others (green color) as Figure 7.4

7.1.2.2 Vuforia and Augmented Reality

The Vuforia SDK makes it possible to build vision-based augmented reality applications for iOS and Android. It uses image recognition to detect and track images and simple 3D objects. It positions the virtual objects in relation to the real world images captured

```
private List<String> placesNearBeacon(Beacon beacon) {
    String beaconKey = String.format("%d:%d", beacon.getMajor(), beacon.getMinor());
    if (PLACES_BY_BEACONS.containsKey(beaconKey)) {
        return PLACES_BY_BEACONS.get(beaconKey);
    }
    return Collections.emptyList();
}
```

Figure 7.6: Ibeacon Information

through the device camera and updates its position in real time. Vuforia also provides a Unity extension. Using this extension allows developers to build augmented reality applications that are cross-platform compatible. It is free to use, but only provides free users with a limited amount of image recognitions per month. The amount of recognitions available for free was more than enough to develop, test, and evaluate the application described in my thesis.

In my thesis, i used Augmented Reality for 2 purposes:

- In event quiz that allows visitors to find a specific way to go to main stage. Using Augmented Reality for Wayfinding, i can show users in real time where users should go as Figure 7.7a.

- In trail option that allows visitors to watch a reality view of artefacts as Figure 7.7b.

(a) Augmented Reality for Wayfiding   (b) Augmented Reality for artefacts
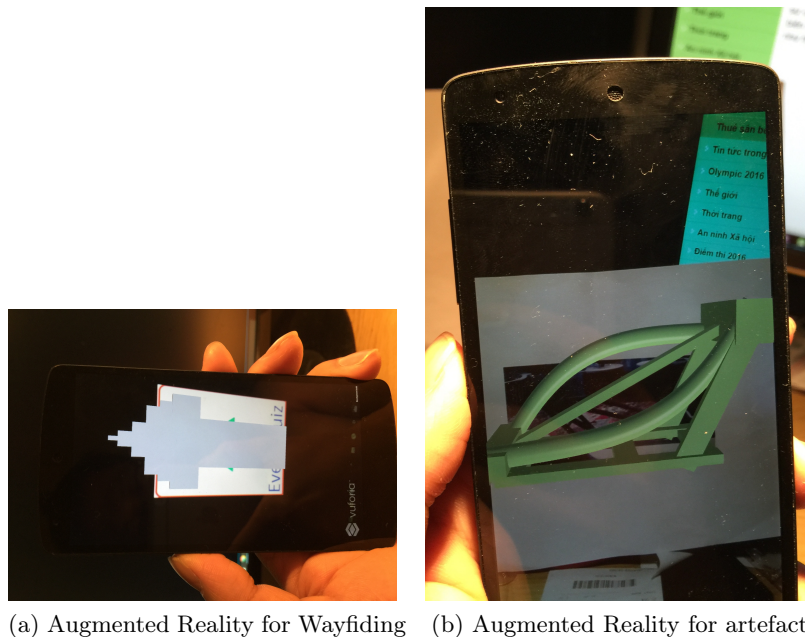
Figure 7.7: Augmented Reality Display

In order to implement these functions, i used tools and soft-wares as follow:

- Unity 3D is used to create 3D models as Figure 7.8.
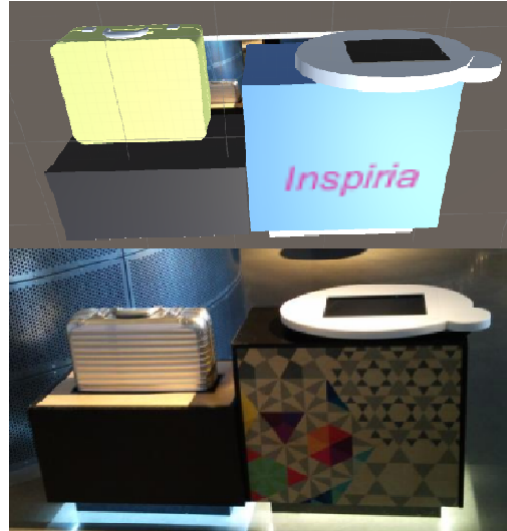
Figure 7.8: Model textures.

- The Vuforia Unity Extension is used to implement my AR system. Figure 7.10 provides an overview of the application development process with the Vuforia platform.

The detailed process is described as follow:

- 1. I created unity project with 3d models using Unity 3D.

- 2. I uploaded the input image for the target that i want to track as Figure 7.9. The target resources can then be accessed by the device.

- 3. I opened the Target Manager site and download the image targets in unity editor format to match my development option.

- 4. I imported the targets unity package into unity project; arrange the targets in a scene. In addition, the Inspector panel of unity was used to adjust object settings, configure the component attributes, public variables value, and the relationship between objects

- 5. The project exported and link to my android project.

- 6. Artefact models were presented on mobile devices.

7.1.2.3 Google Cloud Messaging

For the visitor-host communications in Event Quiz Option, the visitors come to main stage and receive a common code form host. When host enable the quiz, all users can
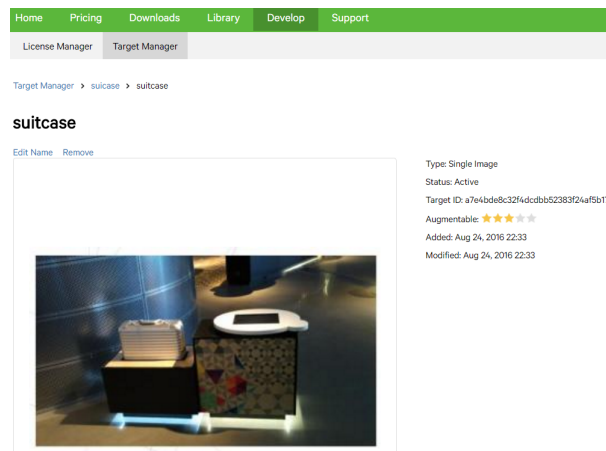
Figure 7.9: Upload target picture to Target Manager.
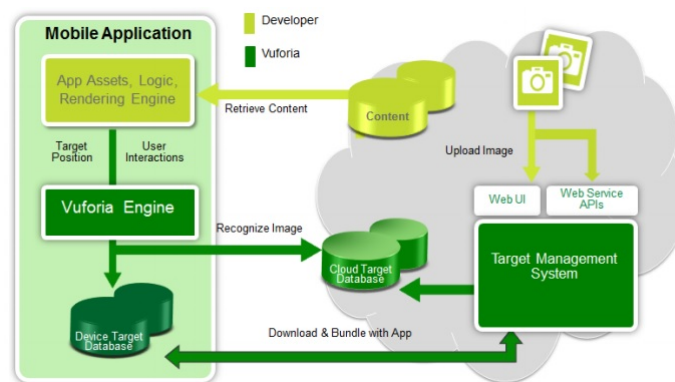
Figure 7.10: Data flow diagram of the development process.
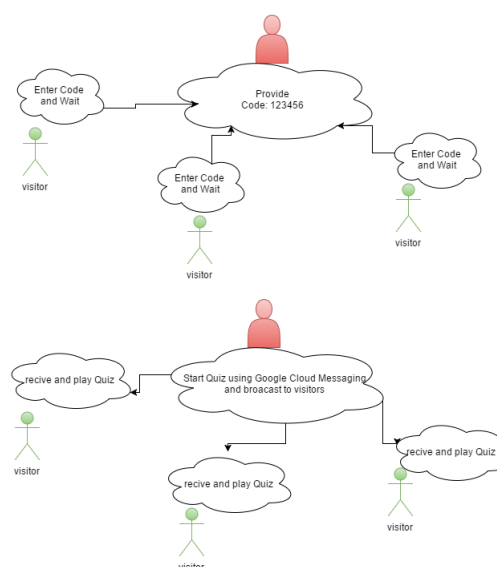
Figure 7.11: Overview of using GCM for Event Quiz
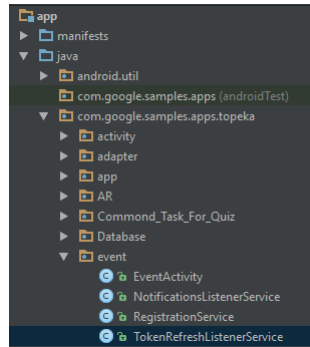
Figure 7.12: Event Code

access to event quiz simultaneously. Therefore, we need to maintain a connection between the host and visitors and implement a method to access simultaneously.

In order to implement this function, i used Google Clound Messaging (GCM) as Figure 7.11 that is a service acting as intermediary between server (host) and visitors. With GCM, Google's Cloud Connection Server, often referred to as CCS, manages the persistent connections. It also makes sure that the communications are delivered securely and reliably.

Client Side

- Firstly, i have to get a Server API Key and a Sender ID that to identity the server side and the client side. To get the API key and the sender ID, i created a new project in the developers console (https://developers.google.com/mobile/add).

- Secondly, because GCM identifies Android devices using registration tokens. Therefore, my app must be able to register itself from every Android device on which it is installed, i created a new Java class called RegistrationService.java as Figure 7.12. This class is actually an IntentService which to registry a service for Registering the Client (the sender ID) on a background thread. TokenRefreshListenerService.java is used to handle Registration tokens periodically. I started the Registration Service by using RegistrationService.java.

- Lastly, GCM automatically displays notifications from server (host) as soon as they are received. I created a new Java class called NotificationsListenerService.java as Figure 7.12 and make it a subclass of GCMListenerService to get these notifications.

Server Side

I created a Python script (send.py) that can generate and send push notifications to all the Android devices of visitors on which my app is installed. This notifications were used to enable users to access event quiz. The send.py contains a the server API key that is part of every HTTP request and notification content as Figure 7.13.

Figure 7.13: server side

Figure 7.14: Turn questions (under JSON File) to web-client using PHP

7.1.3   Website-platform

I created a basic website with HTML and CSS, the website will wait for data from server. To get data for displaying, webclient will send a request to web server. The web server will then reply by sending quiz and user information back to web client. This answer is an JavaScript Object Notation (JSON) file, which will be easy to understand and use as Figure 7.14. The diagram for Javascript functions and PHP are as Figure 7.15.

- Firstly, web client (host) uses Javascript to establish a MySQL Connection to database using loadJson() function as Figure 7.16. LoadJson() function actually called a getJsonQuestion.php located on server which will return questions under Json file as Figure 7.17a

- Secondly, questions are set orderly and rendered by a number of loop depended on number of questions as Figure 7.17b.

- Thirdly, after displaying whole question, the loop is ended and LoadJsonScore() function is called as Figure 7.18 to get user score. LoadJsonScore() actually called a getJsonScore.php located server that will return a orderly scores under Json file as Figure 7.19

- Lastly, Json file will be converted and displayed on last page using renderResults() function as Figure 7.20.
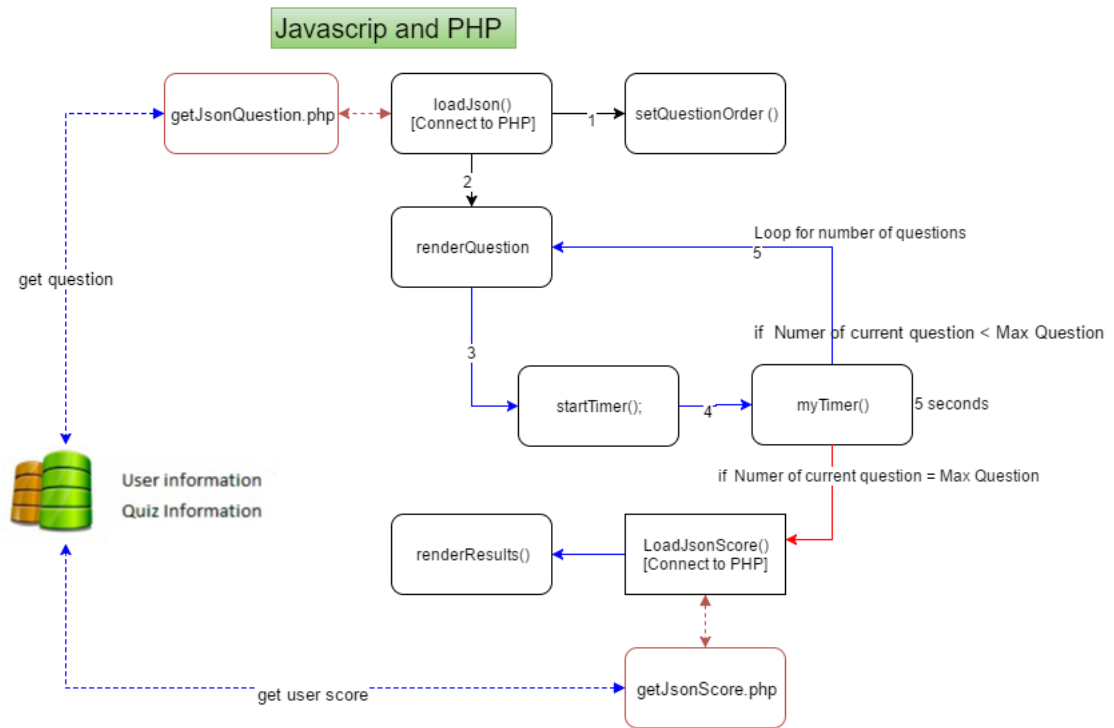
Figure 7.15: The diagram of website

Figure 7.16: Web-client gets questions from Mysql using Javascript

(a) Server retrieves questions from MySQL

(b) Web-client renders the questions using Javascript

Figure 7.17: Retrieve and render questions

```
function LoadJsonScore() {
    console.log("LoadJsonScore");
    question_json2 = new Array();
    var jqxhr = $.getJSON('getJsonScore.php', function(result){
        $.each(result, function(i, field){
            question_json2.push(field);
        });
    }).success(function() {
        renderResults()
    });
}
```

Figure 7.18: Web-client loads user scores using Javascript

```
<?php
$servername = "mysql11.000webhost.com";
$username = "a1492928_oslo";
$password = "         ";
$dbname = "a1492928_oslo";

$conn = new mysqli($servername, $username, $password, $dbname);
// Check connection
if ($conn->connect_error) {
    die("Connection failed: " . $conn->connect_error);
}
$result = $conn->query("SELECT name,score FROM users ORDER BY score DESC LIMIT 0, 5");
//$result = $db-> query ($sql3);
if ( ! $result ) {
    echo mysql_error();
    die();
}
$to_encode = array();
while($row =mysqli_fetch_assoc($result)) {
    $to_encode[] = $row;
}
echo json_encode($to_encode);
mysqli_close($conn);
?>
```

Figure 7.19: Server retrieves scores from MySQL

```
function renderResults(){
    console.log("renderResults");
    var test = $_("questiondisplay");
//  test.innerHTML = "<h2>You got "+correct+" of "+maxNumberOfQuestions+" questions correct</h2>";
    test.innerHTML = "<h2>Congrat !!!!</h2>";
    $_("test_status").innerHTML = "Test Completed";
    $_('timeleft').innerHTML = '';
    test.innerHTML = "<h3>"+"Congrat!"+"</h3>";
    test.innerHTML += "<label>"+question_json2[0].name +"  has. "+ "<strong>"+question_json2[0].score+ " points"+"</strong></label><br>";
    test.innerHTML += "<label>"+question_json2[1].name +"  has. "+ "<strong>"+question_json2[1].score+ " points"+"</strong></label><br>";
    test.innerHTML += "<label>"+question_json2[2].name +"  has. "+ "<strong>"+question_json2[2].score+ " points"+"</strong></label><br>";
    test.innerHTML += "<label>"+question_json2[3].name +"  has. "+ "<strong>"+question_json2[3].score+ " points"+"</strong></label><br>";
    test.innerHTML += "<label>"+question_json2[4].name +"  has. "+ "<strong>"+question_json2[4].score+ " points"+"</strong></label><br><br>";
    test.innerHTML += '<button onclick="location.reload()">Re-test</a> ';
    setQuestionOrder();
    correct = 0;
    clearInterval(myVar);
    return false;
}
```

Figure 7.20: Web-client renders the questions using Javascript

7.2 User Interface

7.2.1 Website

For the purpose of displaying event quiz on big screen which is easy for visitors to follow, i designed a website which will be handled by host standing on stage. I used HTML and CSS to design my website interface as 7.21a, and used Javascript (Scripting language)

which is used mainly in my webpage to make websites interactive.

The description of operation is as follows:

- Firstly, host chooses a event topic as Figure 7.21a.

- Secondly, questions will be displayed as Figure 7.21b.

- Lastly, a story board will display visitor's scores that lists 5 the highest individual scores in event as Figure 7.21c. The winner in on the top of list.

(a) Choose a topic (b) Question display (c) Scoryboard

Figure 7.21: WEBSITE

7.2.2 Mobile Application

7.2.2.1 Main Menu

For application, it is optional for users to enter their information as screen shot 7.22a, they can also upload their profile images from mobile storage or camera as screen shot 7.22b. Later on, the main options will display options as Casual quiz, Event Quiz and Trail as Figure 7.22c.

7.2.2.2 Event quiz

In order to make it easy for all visitors to find the main stage displaying the event quiz, i created the idea of **"Go To Stage"** and used the Augmented Reality technology described as section of "Technical Description" to implement this function. The description of operation is described as follows:

- Visitors push the button labeled **"Go To Stage"** which will turn on the devices camera

- Visitors scan an image target on the floor as screen shot 7.23a

- After a second or two of scanning, the visitors can experience augmented reality displaying the way to go to stage as screen shot 7.23b.

(a) User Information　　　　(b) Profile Tab　　　　(c) Main Options

Figure 7.22: Main Menu

(a) Event Screen　　　　(b) Augmented Reality
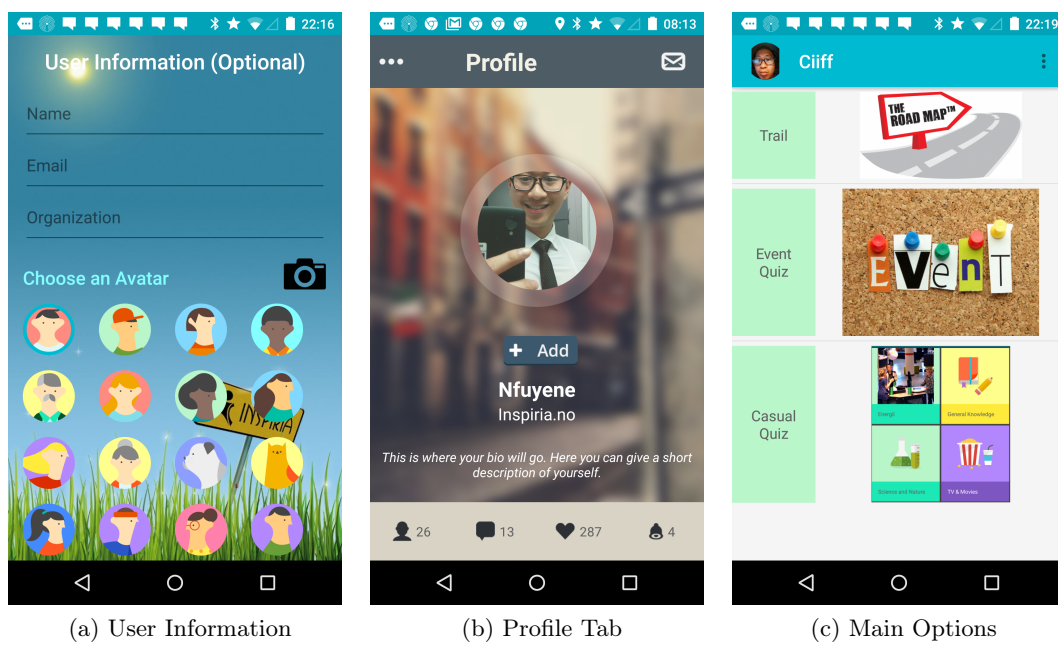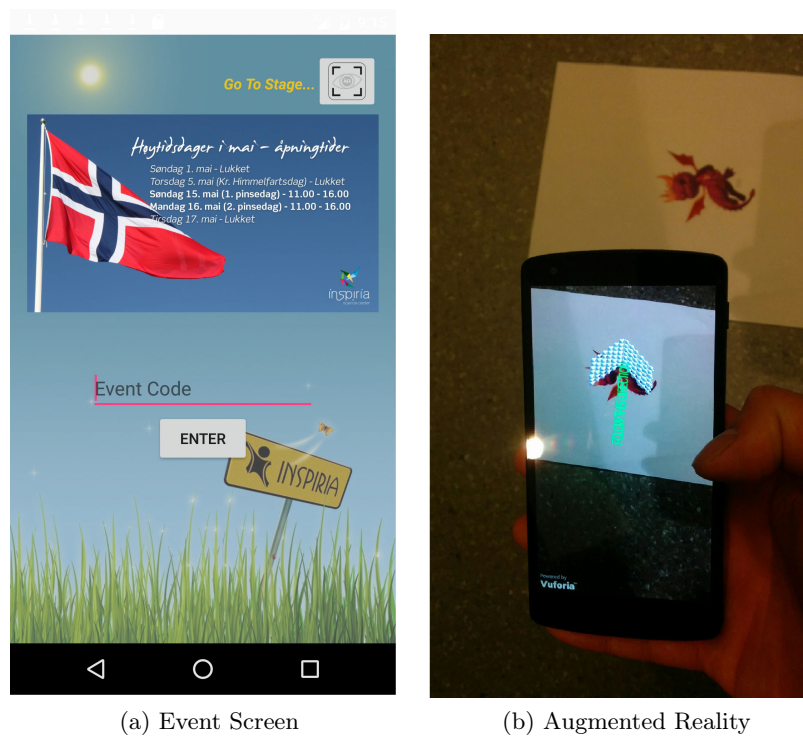
Figure 7.23: Go To Stage

When visitor comes to the main stage.

- A person hosting the event will provide a code, which is to identify a special event

– The visitor uses this code to access the quiz as Figure 7.24. The quiz is based on TOPEKA application from Android. Each question is displayed during a limited time (5 seconds) with one correct answer as screen shot 7.24b. After one question has been submitted, the next question will show until the last one.

– There are a summary screen and ranking screen at the end of the game as screen shot 7.24c, 7.24d

– Host will announce the winner and give a reward for the winner

(a) Check Code   (b) Quiz Display   (c) Summarize   (d) Ranking
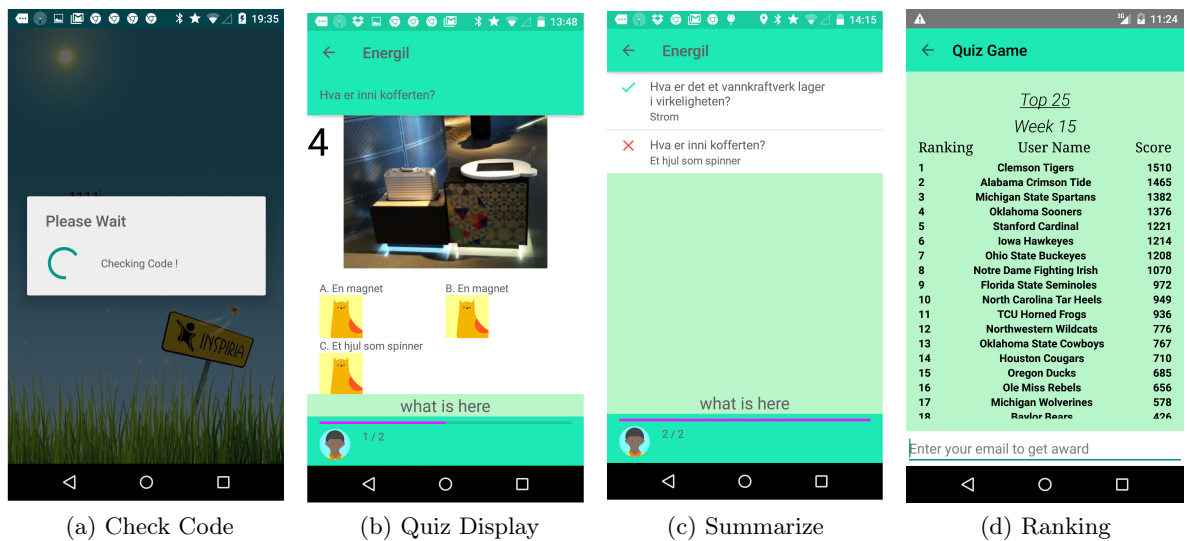
Figure 7.24: Access To A Event Quiz

IMPROVEMENT: Based on feedbacks from users for low-definity prototype, i added a information table displaying a special event to screen as Figure 7.23a.
i also used Augmented Reality for finding a way to main stage that make more interesting for visitors.

7.2.2.3 Casual quiz

In order to test visitor's knowledge of museum, i created a casual quiz based on TOPEKA application from Android. This option can be used for all of users who want to explore our museum as Figure 7.25.
The visitors can select one of several categories as screen shot 7.25a. After selecting, casual quiz will start with question and answer like Event Quiz. Pressing back button will take the visitor back to the categories screen. There are a summary screen and ranking screen like Event Quiz at the end of the game. The visitors can test their knowledge as screen shot 7.25c and their rank as screen shot 7.25d.

| (a) Categories | (b) Quiz Display | (c) Summarize | (d) Ranking |
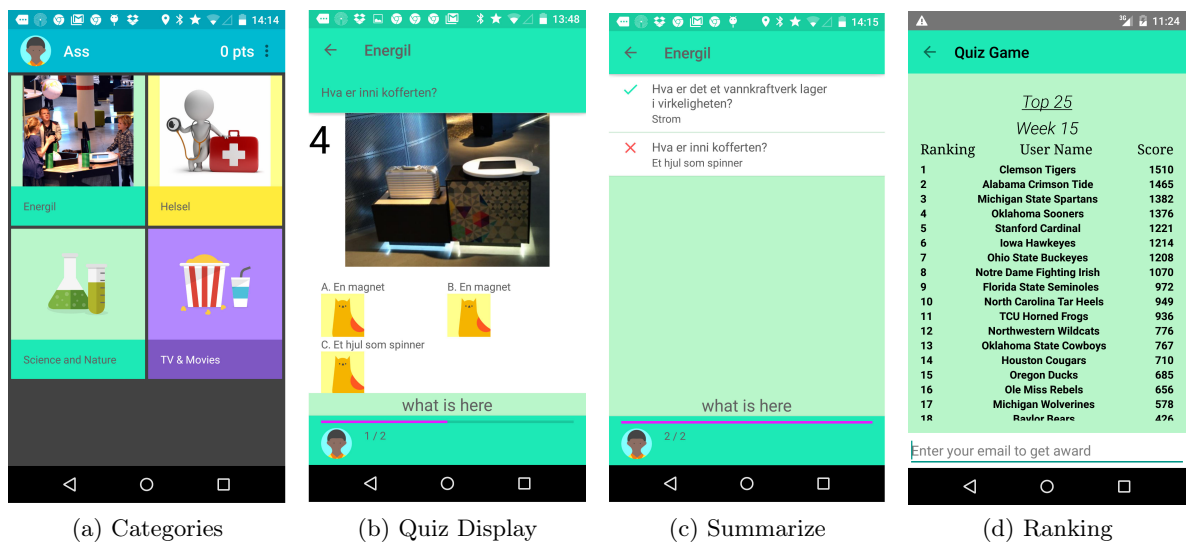
Figure 7.25: Casual Quiz

7.2.2.4 Trail

In order to implement a trail which helps users determine the position of artefacts inside our museum, i used iBeacons device based on the knowledge from literature review. In addtion, i implemented information tabs including images, texts, videos and Augmented Reality view .

As the screen shot 7.26a, Users can see nearby location (red circle) and see other stations (green circles) or find a direction to interesting stations like a google map. In addition, the information about station will be displayed manually by tapping station points on trail, or automatically suggest when the users come close to station. The information can also be displayed under images as screen shot 7.26b, video as screen shot 7.26c related to our artecfacts.

Especially, my application can support Augmented Reality view by pushing "Scan" in screen shot 7.27a and scan image targets putting on below artefacts. The camera will start up, detect image targets and display 3D view right on the phone screen as screen shot 7.27b. For implementing this function, i used Augmented Reality (AR) described as section of "Vuforia and Augmented Reality ".

IMPROVEMENT: Based on feedbacks from users on low-definity prototype, i changed structure of information tab that currently display texts, images and videos as well as 3D as Figure 7.27 and 7.26

7.2.2.5 Guided Tour

Based on feedbacks from users on low-definity prototype, i added a guided tour. Incorporating a guided tour helps a user understand my application's features and
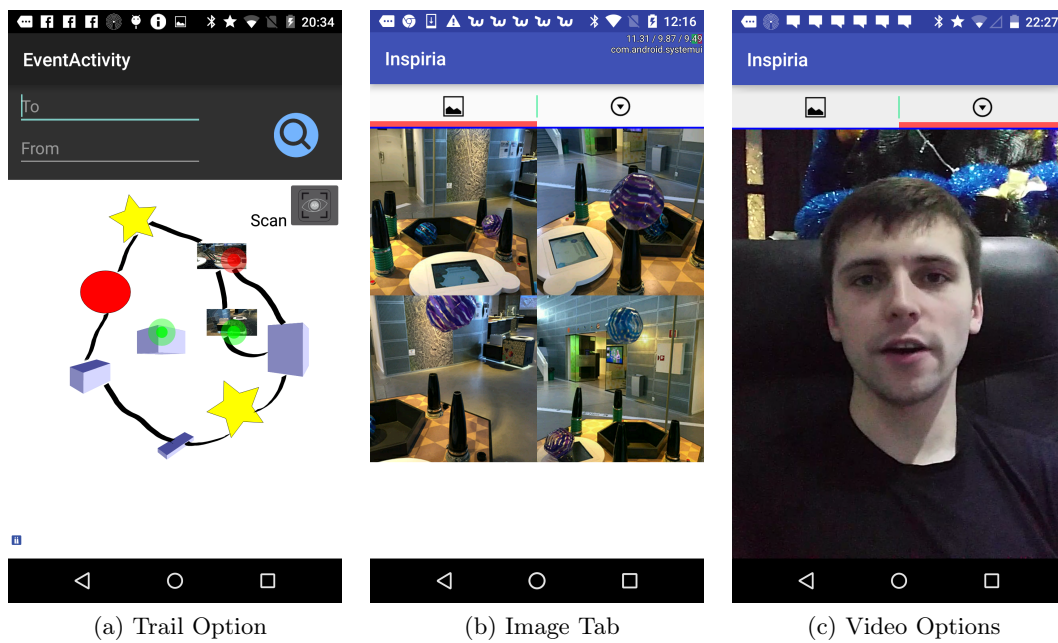
(a) Trail Option   (b) Image Tab   (c) Video Options

Figure 7.26: Trail
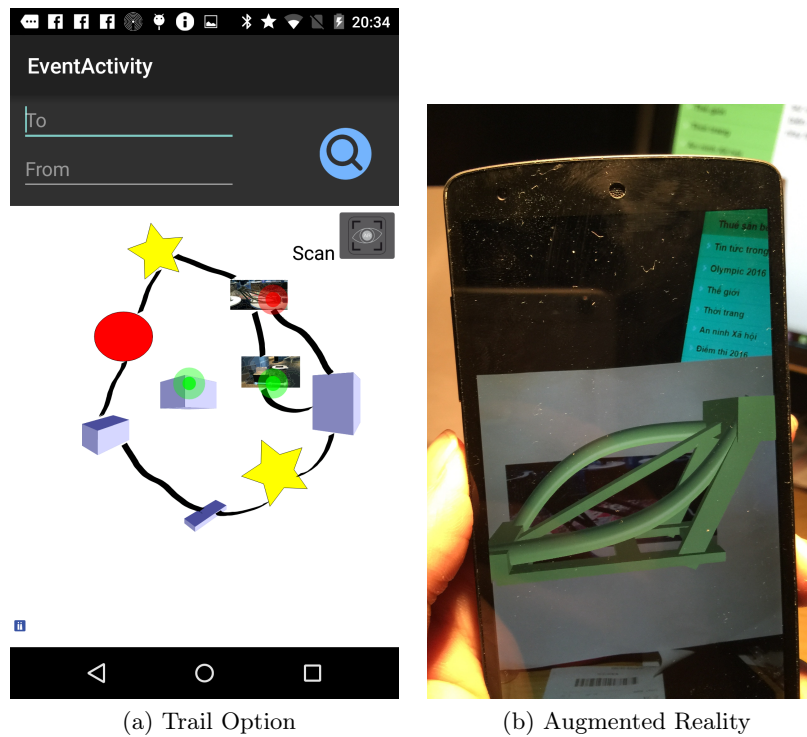
(a) Trail Option   (b) Augmented Reality

Figure 7.27: Augmented Reality View

functions. It is presented during first time use. The tour helps the user learn how to use the app by providing an overview of important functions. The overview is presented in the form of an overlay which casted over my main screens as Trail, Event Quiz, Casual Quiz. Moreover, the tours are brief and easy to skip. For example, Figure 7.28 explain how to access to Event Quiz.

(a) Original Event Quiz   (b) Go To Stage   (c) Code   (d) Enter
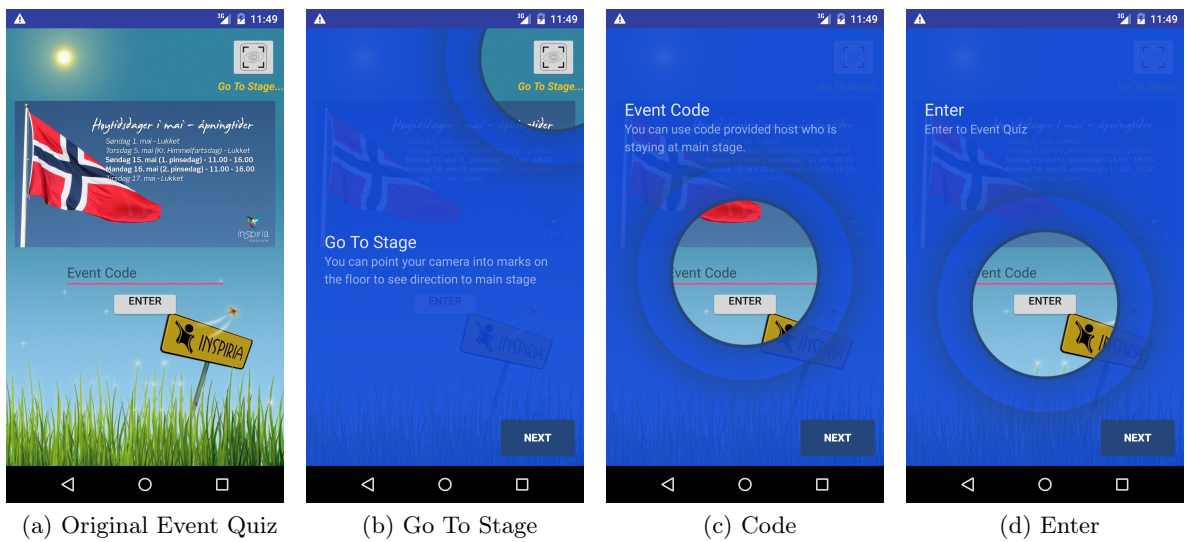
Figure 7.28: Guided Tour

Chapter 8

Usability Testing

8.1 Purpose

The main purpose is to test the expected performance of actual visitor using the new application and materials and to remedy serious problems prior to release. The usability test measured 3 options in my application.

– To test the efficiency of the trail supporting visitors in learning through a trail, i tested how many artefacts student could find, how long they took to find a favourite artefacts, how much they could understand about artefacts.

– To test the efficiency of the event quiz supporting visitors in learning through a special event, i tested how long visitors took to find the main stage, and how many questions visitors could resolve.

– To test the efficiency of the casual quiz supporting visitor in learning through a quiz game, i tested how many questions visitors could resolve after using this applications.

Also, i identified errors and difficulties involved in using the application.

8.2 Problem Statement

– The museum has a number of artefacts in it. The visitors would like to know where to place the artefacts so that he/she is easier to get all artefacts as possible. Also, they want to know how an artefact work .

  * Does my application help visitors find these places ? How can a virtual map in trail option can support this ?.

  * Does my application help the visitors understand an artefact ?. How can an extra information and augmented reality support for this ?.

- The museum often organizes the event quiz that the visitors come to the main stage and answer the question to get the reward.

  * Does my application help visitors find the main stage ?.How can an augmented reality support for this ?.

  * Does the webpage help visitors follow the quiz ? How can a website support for this?.

- The museum has unfortunately been stuck with the stereotype of a quiet solitary place to look at old artifacts or documents. This usually doesn't sound all that appealing to most visitors.

  * Does our museum enrich the visitor experience ?.How can an extra information and augmented reality support for this?.

- Does the my application enhance knowledge about museum artefacts and improve communication skill of visitors after using this application ?.

8.3 User Profile

The point of this phase is to anticipate what happened when real users started using my application. So the best testers were visitors of the Inspiria Museum who were unfamiliar with the Inspiria app. The target group of the experiment consisted of visitors who were familiar with the smartphone or tablet. Other specific skills, characteristics, or habits did not be taken into account during the selection process. Moreover, i did not try to balance age, gender, cultural background or other specific criteria. In total, 15 participants were recruited: 7 were female, 8 were male and both consisted of a wide range of ages (16-65+). The visitors were divided into three groups of visitors resposding 3 options of app (5 visitors/1 option).

In addition, There were 2 educators attended as visitors through our test, 1 educator attended as a host in event quiz. Other staffs volunteered to act as an intermediate for the recruitment of the visitors. A remuneration or "thank you" gifts were provided by me to thank for attending test.

8.4 Test Environment And Equipment Requirement

The test was conducted at Inspiria Museum. I used the real environment including artefacts, main stage, mobile phones, big screen, host and extra devices as follows:

– The phones used for the testing were 2 NEXUS 5. All of the phones ran on the Android operating system and were equipped with SIM-cards. The SIM-cards were needed in order to access the Internet.

– The iBeacon devices were put at each artefact which were used for virtual map in Trail Option.

– Each of the artefacts had it's own unique image targets printed, containing the content it represents which were used for Augmented Reality.

Other necessary equipment included:

– The chairs and main stage as well as big screen are always available at the center of museum which were used for the Event Quiz.

– For collecting information, i used a camera to take photographs and took short videos of visitors doing tasks. I also used notepads, pens to write my notes during observational study.

8.5   Test Monitor Role

The experiment was divided into two parts as follows:

– The first parts required the visitors to complete a set of tasks. The test monitor first initiated setup and then initiated tasks, simulated the particular scenarios neccessary for each task. After that, test monitor went with visitors conducting the task and recorded timing, errors, and observations. visitors were asked to reply on the application, its functions and their own abilities to perform the required tasks. The test monitors only intervened when the visitors appeared to be completely stuck. The test monitors also encouraged the visitors to share their thoughts and doubts while carrying out the tasks, in accordance with the "Think loud"-protocol. Also, test monitor explicitly prompted the visitors for their thoughts when they appeared to be in doubt.

– The second part of the usability testing were interviews. The test monitors printed out the question and invited 6 visitors in 3 groups to take interviews. The test monitor led and conducted open interview with a free discussion with visitors. At the same time, the test monitors took the notes and recorded the answers from visitors

8.6 Methodology

8.6.1 Participant greeting and background questionnaire

Before the beginning of experimentation all visitors were contacted by Inspiria's staff. Explain to them that was a part of a master thesis and that the results would be used in a research. An explanation of how the app will work and its basic function will be given to everybody, making it easier for them to use it during the test. Also, i answered the questions from visitors before trying the app.

8.6.2 Performance Test

The performance test consisted of a series of tasks that the visitors were asked to carry out while being observed. The visitors were given the phones installed the app and asked to walk around the museum for as long as wanted. I personally followed some of the visitors around both to observe them using the app and also if they have any questions underway.
Before starting the test, visitors will be asked to login with their names and emails. After that, each visitor in each group was asked to do the task as follows.

– Trail task (T task) for visitors in group 1: The first task was created to illustrate how the visitors can make use of the trail as a tool to explore our museum. To solve the task, the visitors will choose a trail option and follow an available map. The map will give an overview of the museum, indicating where the artefacts are located. the visitors will then click the red and green points to find information of artefacts. Also, they will use Augmented reality option to see 3d visualization of artefacts.

– Event task (E task) for visitors in group 2:The second task was created to illustrate how the visitors can make use of the event quiz. Firstlt, the visitors will use AR to view how to go to main stage, then they will sit down at the main stages, wait for instruction and then play the quiz. A host will introduce the quiz and start quiz on big screen, show the score board and then give the gift for the winner at the end of the quiz.

– Casual Quiz task (C task) for visitors in group 3: The third task was created to illustrate how the visitors can make use of the casual quiz as a tool to test their knowledge about museum. The visitors will choose Casual Quiz option, then choose a category and play the quiz. A summary will be displayed at the end of each category.

The visitors were encouraged to work without guidance save for the documentation and the product itself. The test monitors asked each visitor to verbalize his or her thoughts if the visitors becomes stuck or hopelessly confused. This helped to pinpoint the reason for the problem and was noted by the test monitor.

During the main performance test, errors were noted for each unique task on the task list. The test monitor also made notes about relevant visitor behavior, comments, and any unusual circumstances that might affect the application. The visitors were videotaped in order to get a permanent record for verification.

8.6.3 Participant Debriefing

8.6.3.1 Observation

i used observation method to investigate how well prototype supported problem statement. Observation were conducted through all the three tasks above.

While visitors were using application freely, i moved into background and watched their interaction and movement in the museum. I looked for general use, technical problems, navigation and other issues connected to usability and functionality.

In order to store information, i created a video footage to capture communication, body language and visual expressions. The field notes were valuable data as well.

8.6.3.2 Group Interview

The three groups were asked to participate and share their thoughts of the experience using the application. Everybody sat around a table with test monitor. It was an open interview with free discussion, where the visitors could speak their mind. I wrote the answers and hear what the visitors felt and thought on the application.

Moreover, we conducted interview with 3 educators that 2 of them took role as visitors and 1 of them took role as a host standing on main stage.

The common structure of my interview was as follows:

- Improvement: How can the application support you in carrying out their tasks compared to tradition method ?.

- Challenging: During testing, the visitors worked well together completing the tasks with a very a short period of time that they was focused on solving the tasks. I considered to problems and how they resolved.

- Utility: This term described how the product provided the right kind of functionality so visitors could actually do what they wanted and needed to do.

- Learnability: As a main purpose, this term described the ability of the product to support learning about artefacts.

– Collaboration: The task implemented in the prototype for the purpose of the testing encouraged the visitors to work as a team. Each member of group will share two phones that required them to work together. I measured how they could deal with this.

8.7   Evaluation Measures

The following fields were collected and calculated:

– Location-Based Services

– Augmented Reality

– Quiz Game

– Extra Information (Pictures, Texts, Videos)

– Webpage

– Error Classification

8.7.1   Location-Based Services Measure

– The average times to take tours through the Inspiria Muesum by using the trail.

– The average times to locate artefacts they wanted to see by using the trail.

– The average times to find an extra information about WC, exit.

8.7.2   Augmented Reality Measure

– The average times to understand how the artefacts works after using Augmented Reality ?.

– The average times to find the main stage at the Inspiria.

8.7.3   Quiz Game Measure

– Percentage of visitors who wanted to choose various topics.

– Percentage of visitors who finished the quiz.

– The average scores of visitors after quiz.

– Percentage of visitors who contacted others (friends, member family) to play the quiz.

8.7.4 Extra Information (Pictures, Texts, Videos) Measure

– Percentage of visitors who agreed that the extra information help them to learn more about artefacts

– The average times to understand how the artefacts works after using the extra information.

8.7.5 Webpage Measure

– Percentage of visitors who followed the Webpage display on main stage.

8.7.6 Error Classification

The percentage of the visitors who finished each task successfully versus those who had errors from which they could not recover. Each error will be classified and a source of error indicated. Error class are as follows:

– Observations and Comments - The test monitors notes when visitors have difficulty, when an unusual behavior occurs, or when a cause of error becomes obvious.

– Noncritical Errors - An individual visitor makes a mistake but is able to recover during the task in the allotted time

– Critical Errors - An individual visitor makes a mistake but is unable to recover and complete the task on time. The visitor may or may not realize a mistake has been made.

8.8 Executing Pre-Testing

Prior to involving the stakeholders in the testing, a pre-test was conducted using an independent non-representative visitors. The test carried out at the museum using the same equipment and accessing the same content as for the real test. The test person had no knowledge about the museum and my application.

The observations were not recorded. Hence the purpose of the pre-test will not be to perform an evaluative session, but rather to run through the planned field testing unveiling potential technological and task-related challenges. This helped establish an overview of the time spent at each task. The feedback collected from the visitors was used to make minor changes to the design.

The visitors seemed to be very interested in my mobile application. Especially, they liked the real time data displaying on a trail with new technologies that they have

never seen before. However, Pre-testing revealed that the trail can not identify artefacts exactly if i put iBeacon devices too closely. Therefore, i put each iBeacon device faraway with others. Moreover, the trail included too many artefacts along with low-speed Internet that made the applicaiton slow. I tried to reduced and deactivated some artefacts in the trails in order to bring the speed up.

Chapter 9

Findings

The analysis is based on the theoretical background, my thoughts and experiences from the development phase and response collected though observation and interview from the different test group. As there were five visitors/group and only two mobile phones, some of the visitors had to share the device.

9.1 Observation

– All of the visitors were satisfied with the interface for accessing the app. The options were simple. All participants were able to login with their name and email without any pre-register.
To access the quiz, the visitors had to enter at least their name. However, all of them entered both name , email, company. The visitors felt that it would be able to have a clearer understanding of the input text field when they have more instructions or hints beside the login page.

– In the avatar option, All of the visitors were satisfied with the interface. 2 visitors took their pictures and used as their avatars, 5 visitors used available avatar, others used default avatar. However, they felt that it would have been better if there was an increase in the size of the avatars.

9.1.1 Task 1-Trail

It was observed that 5 visitors were very exciting to use the mobile and walk around the museum. All of visitors were easy to identify exactly artecacts which they wanted to find.
In more detail, there were 2 small groups of visitors, 1 phone for each group (Group 1 had 3 visitors and group 2 had 2 visitors).

– 3 visitors in group 1 were very easy to locate the artefacts, they first heard information about the app, then worked together to find their favorite artefacts.

  In order to find the artefacts, 1 of 3 visitor hold the mobile phone, after seeing the trail on the phone, they saw around and discussed about where the artefacts were.

– 2 visitors in group 2 were little difficulty to get the right direction. The reason for this was that the application did not show a direction for them. Also, they had not come to museum before.

  In more detail, the 2 visitors in group 2 first heard about instruction, then discussed where the artefacts might be located by using the application. The group then headed in different directions that led they to take 10 minutes for a tour of 2 artefacts and 5 minutes to locate 1 artefact.

After finding the artefacts, all of visitors touched the icons on the trail to read information and interact with artefacts. Especially, They concentrated on the AR option. All visitors were so surprised about the 3D models displaying on their phone. They rotated the camera around the target images to explore more detail. For supporting, all visitors received pop up message informing coming artefacts. This message supported for visitors in finding artefacts more exactly. As a result, they saved time to find the artefact.

However, there were some problem as follows.

– 1 visitor struggled to understand icons relating the artefacts, she asked her friends about these artefacts. The reason for this was that pictures were little small and can not zoom in/out, the visitor also had problem with eyes.

– 1 visitor felt that the icon's color blends in with the background color, he felt that it would be better if there was a dark color for distinguishing the icon more clearly.

– 1 visitor was difficult to identify the icon's color, she confused that green color was nearby, the red color was faraway artefacts.

– 1 visitor was not able to use scan option for augmented reality (AR).

For measuring, all visitors completed this task as Figure 9.1 with results as follows:

– 5 minutes were the average times to take a tour of 2 artefacts by using the trail.

– 2 minutes were the average times to locate a favorite artefact they wanted to see by using the trail.

– No results for the average times to find an extra information about WC, exit.

Figure 9.1: Usability Testing For Trail

- 3 minutes were the average times to understand how the artefacts works after using Augmented Reality.

- 3 minutes were the average times to understand how the artefacts works after using the extra information under text, images, video.

- 100% visitors agreed that the extra information help them to learn more about artefacts

- 100% visitors contacted other members to explore the quiz.

9.1.2 Task 2-Event Quiz

There were also 2 groups of visitors, and 2 educators worked as visitors. Another educators stood on the stage to control the quiz.

- All of visitors sat around the main stage and listened the instruction. They then received the common code from host.

Figure 9.2: Usability Testing For Event Quiz

– The host triggered the quiz by clicking start button, and find the winner via website without any difficulty.

– All visitors were successful in accessing the quiz by using common code. Also, they were able to read the question and select answer without any difficulty. Both group very concentrated on the quiz and worked together.

– 3 of visitors contacted others to answer the quiz. They speak loudly and argued for the last solution.

– All the visitors were successful in identifying the help guidelines for playing the quiz.

However, there were some problem as follows.

– All of visitors felt little stressful because of the limited time and the challenging for the gift.

– 2 visitors just looked at the website and saw around museum, but did not concentrate much on the quiz.

– 1 visitors felt that the text was quite small. They felt that it would be better if the text for both question and answer were more clearly and bigger.

– 2 visitors were difficult to scroll the review tab, they felt that it would be better if review tab was longer and wider.

For measuring, all visitors completed this task as Figure 9.2 with results as follows:

Figure 9.3: Usability Testing For Casual Quiz

- 3 minutes were the average times to find the main stage when using "Go To Stage.." Option. Time counted from the main entrance of museum to main stage.

- 100% visitors finished the quiz.

- 16 points were the average scores of visitors after quiz that had 4 questions/-category and 8 points/question.

- 60% visitors contacted other members to play the quiz.

- 100% visitors followed the Webpage displaying on the main stage.

9.1.3   Task 3-Casual Quiz

- All of 5 visitors were able to understand the categories. Also, they were successful in accessing their favorite categories

- 4 visitors were satisfied about their results, 1 visitors was not satisfied and argued that time was too short.

- All of visitors felt more comfortable because they did not care about the result.

Because this quiz used the same concept as event quiz, they had the same problem as event quiz.

- 1 visitors felt that the text was quite small. They felt that it would be better if the text for both question and answer were more clearly and bigger.

- 1 visitors were difficult to scroll the review tab, they felt that it would be better if review tab was longer and wider.

In addition, there were extra problem as follows.

- All were not successful in receiving their score via email because we did not implement this function.

- Only 2 visitors contacted others to play the quiz, others just looked around and interacted with artefacts.

For measuring, all visitors completed this task as Figure 9.3 with results as follows:

- 80% visitors finished the quiz.

- 24 points were the average scores of visitors after quiz that had 4 questions/category and 8 points/question.

- 40% visitors contacted other members to play the quiz.

9.2 Interview

After finishing the test an interview session took place in a meeting room at the museum. The purpose of the interview was to discuss the experience gathered during the testing, focusing on the research questions. The question is described on Appendix B. During the session, the visitors and educators spoke freely.
The statements in the interview concerns different aspects of the system that my thesis is trying to assess:

9.2.1 Improvement

90% visitor told me that the application changed how they think about a museum. One of visitors said that:

"I did not think that my phone is now useful for me to explore the museum. It really engaged me to explore the machine."

Another one said that:

"I feel i hold every information in my hand and pocket. (He means his phone)"

However, an educator told me that:

"The application is not much useful for me to activate the event quiz and check the winer because i can also do that with Kahoot. but it is useful for me to manage the quiz and users"

Moreover, a visitor argued that using Trail as a method of visiting and learning about artefact is not so different from a traditional visit where a visitor performs on artefact. Another one compared the Trail option to a traditional way of visiting the museum:

"It is pretty much the same. The pictures and videos show a way to use this artefact where was located. It is quite similar to a traditional visit where a person is physically present showing about artefact."

Another one suggested to post all of AR image targets on the website of Inspiria, they want to download and play at home.

9.2.2   Challenging

The visitors said that :

"The Quiz helped me test knowledge, compete against others to get the top position in the ranking and win attractive prizes!"

2 visitors told me that

"The quiz was too hard for me, because i have never come here before. But i think it will be better in next time !"

However, one of them suggested that the app can cause distraction. Because he want to check messages and make a call, the quiz process was then totally disrupted and late.

An educator argued that 5 seconds for each question is too short for kids.:

I think that it will be big challenging for kids to play the quiz, because they do not have time to complete the question. It would be better if limited time can increase to 8-10 seconds/quesiton.

9.2.3   Utility

One of the visitors said that:

"The ideas are so brilliant. The trail was good way for me to find a favorite artefact, extra information also helped me learn more about artefact. Specially, AR technology combined to trail was interesting for me and my kids. However, you should improve performance that was too low to display the trail and extra information."

Another one had the same problem when she touched on an interesting artefact:

"This is annoying. I had to type so much in order to touch artefact on trail, and I can't hit the right artefact on the touch screen."

This problem seemed to be that the visitor tried to use their nail rather than the whole surface of their finger.
One of the visitors said that:

"The trail is inefficient visualization in the small display, I could not zoom in and zoom out the trail"

Another one said that:

"I think that the application just fits for kids and young people, old people can not use this application because of limited technology".

One of visitors argued that the application is difficult and suggested an instruction tab that is :

"I was unable to do tasks if i did not have the knowledge or instruction!"

Moreover, 2 visitors commented that the places in the trail should have text under icon like "rolling machine", "electric machine". Because the images presenting for each artefact were too small to see. 3 visitors also argued that the application should have available tours including the most interesting artefacts.
Furthermore, i received a lot of useful suggestions from educators, one of them suggested that:

"I think that you should change the color of points on the map that green is nearby artefact and red is faraway artefact. Because the green is normally presented for right one and red is for wrong one."

Another educator suggested that:

"The login tab should add more hints or instructions that help visitors know which information is obligatory and which one is optional. Moreover, the overview tab at the end of each quiz should display more question, because I do not want to scroll down to see all of the questions"

9.2.4 Learnability

All visitors agreed that: this mobile apps help them find the artefacts they want faster and more efficiently. They can learn valuable information about aftefacts after using trail an event, casual quiz. The trail and quiz encouraged them to find more information and interacted with artefacts.
One of visitors said that:

"The application helped me stay connected and updated information with museum's activity."

Another one said that:

"That is great to combine technology and learning, we feels that artefact is now more colorful and easy to learn".

Anothe one joked that:

"Now, i dont need to go to museum because i can stay at home, open app and press artefacts on the trail, all information come to me !."

Moreover, all of educators agreed that the application is very interesting for visitors to experience and learn something before and after visiting.
One educator argued that:

"It would more useful if we use casual quiz for both before and after visiting. I think that the content should be flexible that we can change based on our subjects."

One of them even asked me to use it right next school trip.

"Is this application available on the market ?. I want to change the content to fits for each class and used it in my class"

9.2.5 Collaboration

The tasks implemented in the prototype for the purpose of the testing encouraged the visitors to work as a team. Each of the two groups consisted of five members, sharing two phones.

The 90% visitors claimed sharing a device was not a problem. They were able to do the task in collaborative efforts. However, 1 visitors believed the tasks should be solved individually.

Moreover, 95% visitors agreed that: Using the application in the museum could improve their communication skill.

2 visitors said that:

> ”It was a lot more fun because i worked together with my friends.”

> ”I had good debate, discussion and good score.”

Another one revealed that

> "The quiz forced me to work with others, but that was fine!. I had better score and more knowledge. Especially, i have more friend now !."

Moreover, 2 visitors complained that It were annoying because there were 5 persons sharing 2 phone:

> ”It was great experience to work with others. However there were too many people! It were difficult for me to share small screen.”

Furthermore, 3 visitors told me that they liked to work with their friends, special their girl/boy friends.

Chapter 10

Discussion

This chapter will review the findings from the usability testing in my thesis to provide answers to the main research question and its sub-questions.
The main research question in my thesis can be summarized as following:

- How can we make a mobile application which improves the conventional way of visiting the museum and encourages visitor participation both onsite and offsite of the museum space?

The sub-questions of the research is as following:

- What challenges arise when using this mobile application in this museum setting?

- How can a mobile solution enhance museum experience for visitors ?.

The evaluation showed that using mobile phones as tools enhanced experiences at museum and brought big benefits for visitors. The new technology makes them easy and more interesting to experience.
By using grounded theory, I analysed research questions into categories which are Improvement, Educational Purpose, Collaboration and Competition, Challenges.

10.1 Improvement

10.1.1 Trail

The introduction of the Trail as a replacement for the traditional navigation and learning does not by itself influence the user experience much at the museum. However, the use of technology like Augmented Reality combined with Navigation may be used to change the way the visitors interact with the museum.
The application turned the traditional museum with statistic texts and pictures

into the mobile app with audio, 3D models, text, video guides. The new ways encouraged visitors access information and learn about artefacts. In addition, the real-time information on the user's current location helped visitors take less time to find their favorite artefacts and to understand each artefact passing through. The trail could also offer shortest routes based on search option from their location. Moreover, the trail could also take advantage of information on the user's location by providing different types of information on to the user's surrounding area.

For the traditional method: All visitors find their favorite artefacts by themselves or ask others like friends or Inspiria staff. The visitors must also use their visiting card to enable and read instruction under text and images at each artefact. This method sometimes makes the the visitors tired, difficulty, especially elder or disabled people who have problems with visual and health. Also, all visitors on usability testing agreed that they could not overview what is inside of our museum with traditional method both before and after visiting.

10.1.2   Event Quiz

The quiz supported visitors to attend a special event in museum. In addition to the app, I also implemented the website in order to display quiz on the big screen and to trigger content on user's mobile. The evaluation showed that visitor was able, and willing to play the quiz when host wants to start the quiz. All visitors agreed that the website made them easy to follow the quiz. Although time out for each question on the website was not matching 100% as on the apps that can be fixed simply in the future. The evaluation also showed that the visitors saved time to find the main stage by using augmented reality.

For traditional method: Each visitor has no idea about location of the main stage that is sometime difficult to find the main stage. Having no instructions or information ralted to artefacts on the Kahoot website.

10.1.3   Casual Quiz

In order to support for visitors in reviewing their knowledge, especially at off-site locations, i implemented a casual quiz that user can choose various categories and play the quiz to get score. The score will represent visitor's knowledge in specific field.

The evaluation showed that visitor was able, and willing to play the quiz but with lower percentage than Event Quiz. However the visitors had higher scores than in event task because they were less pressure. By contrast, they trended to do the task individually.

This quiz is new solution that help visitors check their knowledge anyplace both onside and offsite of the museum. This means that the visitors do not need to go to the museum, they can stay at home and experience museum.

For the traditional method: Having no solution for checking visitor's knowledge off-site/on-site museum.

10.2 Educational Purpose

As the educators outlined during the interview session, they have certain subjects that need to provide to each class or special group. Moreover, the subjects of interest may be various because each class or group has different approaches to explore, and the they also have different interests and skills like young or elder. Hence it should be possible to adjust the content of the visit and arrange it according to the purposes of the users. This can hardly be accomplished in a traditional museum setting, where the content is mostly very static.

- For the trail, the results from evaluation revealed that the trail can be changed depended on subjects from class or special group like business or company. This can help visitors to understand the special subject that they intended to explore in museum.

- For the quiz, the results from evaluation revealed that we can also create different questions depended on subjects from class or special group like business.

For example: If the teacher want to teach their students about a special subject, he/she can ask the Inpiria staff to include amount of content for event quiz and casual quiz. Also, the teacher can ask Inspiria staff to configure the trail so that the artefacts displaying on the trail fits to their coming subject. In some case, we can provide content instruction to students/group before they come the museum such as sending coming event, quiz, special trail that they will explore in our mueusm. Each of these cases (trail,quiz) requires a special education teacher who know detailed knowledge of subject area content and information about our museum. In addition, Inspiria might team-work with the teacher in order to create appropriate information.

Moreover, The new visitors, who are not familiar with our museum, need to be guided during their visit time. Hence it should be possible to make various trails which the visitors can select and experience regarding to their learning purpose or educational background. As an optional extra, it would me more interesting if visitors can create trails by themselves. Their selects and creations can be used for others as well. It is also very useful for educators who want to improve the system.

10.3   Collaboration and Competition

The evaluation revealed that percentage of visitors, who contacted other members to play the quiz and trail was significantly high with 100% for trail, 60% for event quiz, 40% for casual quiz. The evaluation also indicated that young visitors were more interesting to collaborate with others than elder. Moreover, the visitors liked to work with their peers who have the same age or their friends than strangers.
In the experience of the educator and the visitors using a mobile phone to play the quiz and trail can allow them to work effectively in collaborative efforts in a teams, which was beneficial for the acquisition of knowledge.

  – The concept of the competition between individuals or groups in event trail may help visitors to collect the necessary data in order to be able to answer the question and get the gift. This was also beneficial for the acquisition of knowledge. However the short time for each question and pressure to be the winner made visitors little stressful.

  – For the trail, to save time for each artecfact, the visitors chose to work together. They discussed about where the aretefacts were and which direction should go. Each artefact they passed through, they always discussed and shared their knowledge about how it worked. To have more information, they used the application to view the images, text, videos. Especially, they really liked to view how it worked by using Augmented Reality. As a results, they were motivated to collaborate with others.

  – Furthermore, the contents of the quiz and trail, which required pre-experience and team-work, made a strong effect, and motivation on the overall experience of visitors.

10.4   Challenges

10.4.1   Trail

The evaluation revealed some issues with the design of Inspiria app. 2 visitors argued that information is just transferring from one this format to the other. This does not influence the user experience in itself, and will not necessarily represent an improvement. The challenge is that we need to design a better information experience on mobile devices for visitors.
I got several comments and suggestions on how to improve various aspects of the system, one of suggestion was to include the text under icon in the trail that is easier to see. Another interesting was to post all of image targets relating artefacts

on the website in order to use at home. Also, i got a great suggestion about the available trails that would be used to guide visitors in exploring our musuem.

10.4.2 Event quiz

Although I created positive change for visitors, it also need to improve contents and design in order to encourage more visitors with various ages. Moreover, the evaluation also revealed that that app should have a mechanism to prevent interruption during event time.
The average scores were lower than casual quiz because of stress, this is also a challenge that need to improve.

10.4.3 Casual quiz

The evaluation revealed that that app should have a mechanism to pause the application if visitors want to do other daily activities as SMS or calling someone else. Furthermore, Only 40% visitors contacted other members to play the quiz that need to improve.

Chapter 11

Conclusion

This thesis has investigated the influence a mobile application has on the user experience in a visit to Inspiria museum. It focuses particular interest to the effects of the introduction of mobile technology and the game. The concept targets visitors in Inspiria Museum providing personalized location-aware content, Augmented Reality, Quiz Game.

The thesis used user centered design process that users involved in it from the analyse process to the evaluation of the prototype. The results are based on the feedback collected during usability test.

The prototype consists of a website and a mobile application.

- The website is used by educator to activate the mobile app and display questions in even quiz.

- The mobile application is used to present a trail and event quiz for on-site and casual quiz for on/off-side of the museum.

11.1 Results

This project produced various kinds of results.

- First, understanding about the current Inspiria systems and the underlying problems in them were gained by means of gaming and learning.

- A new mobile system for museum was composed which were ideas under storyboarding presentations. These ideas were generated based on the Open Coding, the Consolidated User Data, Design Drivers from understanding phase.

- Then, A low-fidelity prototype of the Inspia mobile app was brought out. This prototype was generated based on the drivers and design ideas under storyboarding during the user studies in the design phase.

– The Low-fidelity was then tested by usability testing before implementing a high-fidelity prototype. The High-fidelity prototype was characterised by a high-tech representation of the design concepts, resulting in partial to complete functionality that users can truly interact with the application.

– Finally, the high-fidelity prototype's acceptability was evaluated with users from both the viewpoints of user interface design and suitability for its purpose.

Fortunately, the evaluation confirmed the acceptability of the prototype and also discovered interesting aspects about using game and mobile technology for learning. As a result, the visitors were very interesting to use the mobile application with trail and quiz for learning than traditional learning.

Especially, the visitors preferred using the trail than event and casual quiz. The reason was that the trail was integrated new technologies like Navigation and Augmented Reality

Moreover, The feedback collected during usability testing was very effective at highlighting the concept may influence the user experience of a visit to the museum.

– **Collaboration**: The implementation of tasks distributed by the mobile application may support and motivate the visitors in exploring the Inspiria museum, also encourage collaborative efforts. The visitors were interested to work with others in order to get higher score. The content of quiz and trail also motivated the visitors to collaborate with others that improved both their knowledge and skills.

– **Educational Purpose**: The feedback from visitors and educators revealed the new aspects about trail and quiz. The visitors would be more motivational and interested to explore the museum via various trails based on educational purposes. Moreover, these trails could be created by visitors like teachers, students or educators. The quiz also modified based on educational purposes of users that will guide them in exploring and learning.

The evaluation also revealed problems that need to improve such the app content, user interface, app performance. Furthermore, the use of technology influences flexibility and efficiency on not only the the visitors, but also educator. As the results, the educators now can manage user information in order to improve museum. For the app and website, the educators can create and modify content easily and effectively.

11.2   Contributions

The contributions of my thesis are:

– A high-fidelity prototype for the concept, consisting of the website using to display the quiz, as well as a mobile application with Trail, Event Quiz, Causal Quiz. Both are connecting a database where storing the information about app content, users and artefacts.

– Experiences from the visitors and educators in an on-site usability test.

– Exploring new aspects of educational purposes using trail and quiz.

11.3   Future Work

The prototype designed in the work with my thesis is not fully functioning and usable. However, it can be improved to be functioning and usable by changing features in the mobile application
In this section I will present some ideas to future work with the system that surfaced during the different evaluations.

11.3.1   Improvements to the mobile application

Trail

– During the usability testing all visitors can not use search option that would allow the user to simply tap on the artefacts like Google Map. However, this can be implemented by using Dijkstra's algorithm.

– Furthermore, Real-time 3D Object Tracking will be interesting that bring unique real-time 3D object tracking for Augmented Reality. The visitors can view 3d models and functions of artefacts when they point camera right on the real artefacts (Without image targets).

– During the usability testing the visitors experienced issues with the trail which loaded trail and images as well as video very slowly. To resolve this, the application should reduce image quality of the map and its information.

– In order to bring better experience, i will change information's presentations that will be more understandable, enjoyable, and connected to visitors' lives.

– Moreover, 1 visitor suggested that I should post all Image Targets on the Inspiria Website that they can download and play Augmented Reality at home. I found this suggestion very interesting, and the possibility to implement it in the application.

– As a suggestion from usability test, and the discussion chapter, the trail should have mechanism to create various trails based on the educational purpose. This options would help to guide visitors, who are in group like school, company or individuals. Moreover, the option should have different mechanisms for each object, for example, the teacher and educators should have higher rights to create the trails or modify quiz than normal visitors. In order to validate this aspect, I would also create new usability test with the visitors.

Quiz

– During the usability testing a visitor revealed that the quiz should have a option for saving their answers at the end of the quiz. In order to implement this, I will create new Question-Answer table link to User table on my database. Also, I will create user tab on mobile application where users can check their answers whenever they want.

– In order to make the quiz more interesting and reality, the information related to the question like artefacts images should be displayed under 3d models that will make more visualized.

– In my project, i have not implemented a communication protocol between visitors and educators. It will be much better if users can received notifications like subjects, time, days for coming events that make them easier to attend an event.

– The result from the usability testing revealed that 60% visitors liked to work individually in Casual Quiz. In order to resolve this problem, I will suggest to change content that require more tasks for each question that will encourage visitors to cooperate with others in group.

– In order to prevent interruptions in event and casual quiz, I will set higher priority for event quiz and set pause option for the casual quiz that visitors can do other tasks but not affect the quiz process.

In addition to the improvement above, it will be more flexible for visitors if we also implement application on iOS platform.

11.3.2 Improvements to the website

The website is using for displaying the quiz on the main stage for the even quiz. I will suggest some improvement as follows:

– Currently the questions are stored in the database manually using Free Host and MySQL database. This is not practical for every educator who have no

knowledge about technology. So it is better to have a friendly tool for managing questions, user information. The tool may provide statistic information about users and their scores in museum in order to make better strategy for improvement.

– It will be interesting if users can use the website as the event quiz and casual quiz option as the mobile app. This means that users will be flexible to choose platform.

– In order to support visitors in reviewing information, the website should have a user page like app's user tab where displays user history actions such as visiting time, answers, score, also a trail displaying artefacts passed through. As a result, visitors can review structurally what they learned and use it effectively. It will also make visitors easier, more structured to plan for next time.

Appendix A

Questionnaire

- Motivation:
  * What kind of application do you imagine?
  * What is the idea behind the quiz?
  * Who will use the application?
  * How should the people use the application? (scenario)
  * Where and when should people use the application?
- Solution:
  * How does the current prototype function?
  * What do you think about the current prototype?
  * What works well?
  * What is problematic?
  * How do you think the current solution could be improved?
- Perfect solution:
  * What would be really fun to have? (new technology, content,.....)
  * Why would it be fun? (motivation)
  * What is the most important values for you? (expanded, robust, maintainability, secure, ...)
  * How should the system be maintained? (who should be able to manage content)

Appendix B

Interview Question

- 1. How do you experience this way of visiting the museum compared to the traditional way?

- 2. What was fun? Instructive and informative? Interesting? Engaging? Exciting? Challening?

- 3. How did you cooperate?

- 4. How did you experience the use of Trail? Did the trail give you a sufficient amount of information?

- 5. How did you experience the use of Event Quiz? Did the Event Quiz give you a sufficient amount of information?

- 6. How did you experience the use of Casual Quiz? Did the Casual Quiz give you a sufficient amount of information?

- 7. How did you interpret the tasks you were given?

- 8. How did the technology work out? And what could have been done to improve it?

- 9. Could this project have been realized without the use of a mobile phone? If so, how would it affect the user experience?

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