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Days of Future Passed

Mobile augmented reality and its effect on raising architectural heritage awareness

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ABSTRACT

Chances for preservation of cultural heritage depend heavily on public awareness. Recent technological developments, such as 3D urban modelling and mobile augmented reality, offer new possibilities for raising heritage awareness. For a case study in Nijmegen, awareness of the pre-war architectural history of the city is communicated to 2 user groups. One, by presenting digital urban 2D and 3D models on a smartphone using Layar. With the use of audio, the user is guided through the different historical, but now demolished, buildings and architectural styles. Two, users are presented the same information using a printed folder. It turns out that the augmented reality format can contribute to a different experience of the environment compared to the folder, and can be useful for communicating spatial or topographical knowledge. The use of 3D models was also experienced positively, because the user can walk around and view the model from different perspectives. However, the novelty of the medium and technical specifications of current smartphones proved to be drawbacks for effective knowledge communication.

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CHAPTER 1 INTRODUCTION

1.1 CULTURAL HERITAGE IN THE DIGITAL AGE

A lot of institutions in the field of cultural heritage have started to embrace new technological developments in interactive (social) media (Champion and Dave 2007). Applications such as digital audio tours, virtual web-based 3D environments of exhibition halls (Milekic 2007) and more recently mobile augmented reality are becoming increasingly popular (Flynn, 2008).

Augmented reality is a technique that enables users to overlay digital information on the real world (Carmigniani, Fuhrt et al. 2011). Where virtual reality immerses the user in a virtual world completely, augmented reality combines the real with the virtual. The technique has been around for quite some time, but has always been limited in access and application. Recent advancements in mobile PDA's and smartphones have enabled the development of augmented reality software for commercial use. Commercial augmented reality software makes it possible for digital representations of cultural heritage to be projected on small handheld devices, enabling users to highlight the importance of landscape and cultural heritage by making the invisible visible (Joye, De Muelenaere et al. 2010). The projection of features such as video, audio and text offer a lot possibilities, as well as interactivity by enabling user data input (van Lammeren, Goossen & Ligtenberg, 2010).

New digital applications influence the way people experience cultural heritage. When visiting a historic site, the cultural experience is not just comprised of looking at artefacts, architecture or paintings, but also by the experience of being there (de Boer, Voorbij et al. 2009). It is argued that this feeling of context is lacking when it comes to digital heritage, and research in this area has started to emerge focused on cultural experience through phenomenological knowledge production and user perception (Flynn, 2008). This is a concept that looks beyond just a visual representation of heritage objects. It integrates the question of how people experience heritage through virtual representation compared to real physical objects or places. The phenomenological approach is also used to explore "new methods for capturing, storing and representing qualitative data" in the field of landscape perception (Nijhuis, van Lammeren, & van der Hoeven, 2011). Cultural values, being a part of the landscape, might therefore benefit from such an approach.

Mobile augmented reality, a new accessible technique in the field of cultural heritage, offers new research possibilities when it comes to user experience and perception (Flynn, 2007b). The combination of being on a location in person and viewing digital heritage on top of reality might be a possibility to bridge the gap between simple digital representation of cultural heritage and an immersed and embodied cultural user experience.

1.2 Problem Definition

1.2.1 Virtual cultural heritage

Cultural heritage is often hardly visible for the common observer. Because of this invisibility there is often insufficient awareness of heritage in society, leading to low support for preservation. Two of the main causes for this problem are the invisibility of most historical artefacts and the absence of historical and/or spatial context (Joye, De Muelenaere et al. 2010). This makes it difficult for people to imagine the original grandeur of culturally rich locations. In order to make the invisible visible, digital representations of cultural heritage objects could be used.

The visualization of cultural heritage through digital technology is a well-established field of research. Digital reconstruction of historical objects was introduced as early as the beginning of the 1980s. Since then digital media, which have become increasingly more complex and interactive, have been used to reconstruct historical sites and spatial contexts around the world. (Forte and Siliotti 1996)

Authenticity is one of the cornerstones of cultural heritage (Flynn, 2007a). It claims to realism, some form of scientific truth and historical validation. But the creation of realistic virtual environments of disappeared cultural landscapes is problematic (de Boer, Voorbij et al. 2009). There are often data imperfections in historic sources, a lack of automation in the creation of virtual environments (which makes it a labor intensive activity), as well as a poor definition of appropriate visualization techniques. Just like the creation of maps, digital visualizations are subjected to the bias of their creators and the purpose for which they are made. In light of such matters, Sheppard (2000), among others, therefore argues that digital visualization of (historic) landscapes is a powerful tool, and should be governed by a code of ethics that ensures a reliable result.

1.2.2 Virtual heritage experience

Besides practical difficulties, digital cultural heritage also faces a user oriented problem. An accurate representation of cultural heritage also depends on what users perceive as realistic. A simulated representation is always more or less an abstracted version of reality (Lange 2001). The creators of landscape visualizations should therefore ask themselves what degree of realism is needed. For example, de Boer (et al. 2009) suggest that “landscape painters and cartographers were able to capture essential landscape characteristics without creating a very realistic representation.” This implies that non-photorealistic representations (NPR) also show a lot of potential. Moreover, research has shown that photo realistic augmentation can result in little initial visual impact, as users can sometimes not discern what had been added (de Boer, Voorbij, & Breure, Towards a 3D Visualization Interface for Cultural Landscapes and Heritage Information, 2009). These kinds of situations are inappropriate when the designer wants to direct the user’s attention. Visualization styles should therefore be in line with the intended use.

Historical sources are not by definition objective, as the creators of those sources have only portrayed an interpretation guided by their own perception. Subjectivity is therefore inherent to historical data; an important shortcoming that should be taken into consideration. Virtual heritage projects should therefore also be considered as interpretive exercises, and participants should realize that the reconstruction of a historical place can only be partial (Champion and Dave 2007). Because interpreting historical sources is subjective, creating detailed historical models can “falsely insinuate a greater degree of certainty” (Joye, De Muelenaere et al. 2010).

However visually attractive, digital representations also raise questions whether virtual heritage environments are useful (Forte, 2007). One of the main goals in heritage visualization is to communicate an experience, or a sense of being (Champion and Dave 2007). A virtual representation should therefore be able to influence the understanding of the cultural value and significance of historic sites. It is argued that this goal cannot be achieved by mere static digital representations. Instead, one should explore the possibilities of a more immersive technique, because an understanding of the past is "experientially derived through a process of embodied communication rather than through a separate presentation." Material culture is derived from context, not just from single objects (Forte & Siliotti, 1996).

Visual immersion and interaction are therefore important aspects of the integration of cultural values in visualization techniques, but the precise nature of the relationship between representation and user experience is quite complex and remains uncertain.

1.2.3 Augmented cultural heritage

A recent development in digital media techniques that can be applied in order to communicate digital heritage is mobile augmented reality(Keating, Guest et al. 2011). Keating et al (2011) define mobile augmented reality as a technique that "combines the real and the virtual, it is interactive in real time and it is registered in 3D". The mobile aspect constitutes the accessibility using a smartphone.

Mobile augmented reality could assist in demonstrating the importance of cultural heritage by drawing attention to remnants and visualizing disappeared artefacts. It seems like mobile AR could be suited as a "contemporary communicator of social memory and remembrance" (Flynn, 2008). Because it permits a simultaneous viewing of both real and virtual data, an immersion of the viewer in the environment is made possible (Refsland, Tuters et al. 2007). In other words: it enables the user to view past and present scenes together.

Augmented reality can play an important role in the conservation of cultural history (Portales, Lerma et al. 2009). It can help to improve support in society for heritage, create opportunities for the tourist sector, articulate social memory in a contemporary manner and assess future spatial interventions. It can provide a platform for better communication and understanding of historical buildings, improving the chance of their conservation (Xiao et al. 2007).

1.3 Research objectives

1.3.1 Research goal

In order to improve awareness and preservation of cultural heritage, educational and recreational institutions could benefit from better communication of cultural values through modern interactive media. Creating a digital representation of cultural heritage is however not without issues. Opinions seem to differ on the quality of source material and the sense of realism and presentation format of digital models. This question in turn influences the cultural heritage experience and the potential for increasing heritage awareness.

The improved availability of augmented reality applications offers new possibilities for communicating cultural heritage and raising awareness. The goal of this research could therefore be formulated as follows:

To improve the awareness of cultural heritage by visualizing digital architectural heritage through mobile augmented reality techniques.

1.3.2 Research questions

The main research goal can be divided into the following research questions:

1. *What constitutes the awareness of cultural heritage?*

In order to research heritage awareness it is important to understand how people experience cultural heritage. Is it just about looking at places or artefacts, or do context and atmosphere also contribute? Within this topic the visual, but also the psychological aspects that shape a cultural experience are researched. Not only the way people experience objects, but also the way people perceive space is of interest here.

2. *How can cultural heritage be visualized digitally?*

Different ways of visualizing cultural heritage are explored. Aspects covered in this topic are types of digital visualization, such as 2D and 3D, static and dynamic, but also the sense of realism and amount of detail are of importance.

3. *How can digital heritage models be communicated using mobile augmented reality?*

Besides visualization types, the ways of communication through modern technology are also reviewed. Effective interaction between user and technology is essential, the type of augmented reality used should therefore also adhere to certain standards. In this step the practical integration of the digital models in Layar is researched.

4. *How can an improvement of heritage awareness be measured?*

In order to determine whether digital cultural heritage and augmented reality can influence the awareness of heritage, the sense of awareness needs to be measured. This is the main focus of a user survey, where the digital heritage models are presented to the public using a mobile application on a smartphone in order to measure a possible increase in heritage awareness.

1.4 READER GUIDANCE

This research report is structured in the following way. First, the theoretical background used for this study is described in chapter 2. The three main components; heritage awareness, digital modelling and augmented reality are explained in order to clarify the research context and provide argumentation for choices made in chapter 3. In chapter 3 the research design is presented, including the methodology used for answering the research questions posed in chapter 1.3. The results of the digital modelling and augmented reality components are presented in chapter 4, the survey outcome for measuring heritage awareness is presented in chapter 5. Finally, the conclusions, discussion and recommendations of, and reflection on, this study are presented in chapter 6.

Chapter 2 Theoretic background

This study has three main components. First, the search for a definition of heritage awareness and ways to improve the awareness level using digital media. Second, the visual communication of digital heritage through the modelling of historical buildings. Third, a medium called mobile augmented reality to function as a communication device in order to present the digital models and heritage information.

2.1 Awareness and perception

2.1.1 Heritage Awareness

Awareness is a concept that can be applied to many different fields of research. According to Gyan (et al. 2010) there has not been a lot of research on awareness in the field of cultural heritage among residents or visitors of heritage sites. Despite the fact that the visitors themselves are the most important factor in guarding heritage values. So what constitutes awareness? Gyan (et al. 2010) measure heritage awareness using two factors: knowledge and behaviour. "Knowledge is indicated by whether people know of any historic buildings that have been demolished or otherwise lost; and behaviour is defined by whether or not they have visited historic buildings". It is therefore argued that heritage awareness consists of having the notion it exists, and visiting the heritage site in person.

Key elements for raising awareness and improving chances of preservations are therefore accessibility and promotion; people have to know it exists. But when is heritage considered as heritage? Some scholars also emphasize the process and engagement of heritage with the public; heritage has to be experienced for it to become heritage (Smith, 2006). Considering the experience and process element as a core of heritage, Smith (2006) defines heritage as a cultural and social process. It is not just the object itself, heritage constitutes the experiences people have when encountering heritage or witnessing historic events. At the same time heritage is also considered a process of remembering and the creation of new memories (Flynn, 2007). It can serve as a mediator for cultural and social change or values and is a core element of the creation of the identity of time and place.

So even though the importance of historical buildings, objects and artefacts is often cited as the core of heritage, there is more to heritage than just physical encounters; it is also about psychological processes. According to McIntosh (et al. 1999), heritage visitors go through three distinct psychological processes when they visit historic sites and buildings: reinforced assimilation, cognitive perception and retroactive association.

During the reinforced assimilation process, visitors reflect on the past and compare the past with their present lifestyle. They observe a change in scenery or situation, and try to understand what constitutes this change. In the succeeding cognitive perception process, people attain new insights and information from their visits to heritage sites. The information received enhances their understanding of the past, but it is not assimilated with personal experience. Many visitors think deeply about a past which they can personally remember and the things seen at heritage sites therefore reflect personal experiences or meanings derived from similar situations.

This theory is however based on the assumption that heritage visitors are engaged, critical, educated, thoughtful or mindful. But according to Cameron (et al. 2000) visitors' interest in history is not equal to the visitors' knowledge of history. And the reasons for people visiting historical sites can be divided into 3 categories: ‘heritage experience’, ‘learning experience’, and ‘recreational experience’ (Poria, Butler, & Airey, 2003). Cameron and Gatewood’s (2000) study found three similar groups, citing ‘personal experience’, ‘information/education’, and ‘pleasure’ as main incentive to visit historic sites and museums. According to McIntosh and Prentice (1999) the third group in both classifications is comprised of passive and uncritical heritage consumers; they’re simply there to be entertained.

Evaluation of heritage

Heritage objects have certain specific qualities that adhere to people’s aesthetic preferences. When evaluating heritage, the word “value” is often used. This could also be translated as “affection” or “feeling”, which has strong subjective connotations (Coeterier, 2002). There are four major criteria that determine the evaluation of heritage such as historic buildings: form, function, information and familiarity. *Form* consists of beauty (material, colour, proportion), completeness (presence of relevant parts, contextual fit, no deviating details), uniqueness (individual expression, authenticity) and good workmanship (artistry, craftsmanship). A building’s *function*, when it comes to heritage, is less important than its form. For instance, when a building is no longer used for its original purpose, people stressed that it is important that the building’s form is to be preserved. *Information* is about the buildings’ identity and background story. Information gives a building a place in history and in our common cultural heritage. But also emotional ties and *familiarity* are a significant influence on the experience of heritage.

Concluding

All of these values can contribute to different kinds of heritage awareness, for each person has unique preferences for how they experience heritage. There are a lot of different types of heritage awareness, perception and different types of heritage visitors. The process of raising awareness though, seems to be revolving around communicating information and users being able to recollect this information; it’s an educational process. This suggests that the key to improving heritage awareness for this study is presenting information in an educational way to visitors that have affinity with the heritage topic.

2.1.2 Perception of space and place

In theory, augmented reality adds a distinct spatial component to information when compared to static presentations (Bimber & Raskar, 2005). It is therefore interesting to research whether this technique has a significant impact on the way people perceive or experience the study area. The definition of space and function is highly subjective, and has been debated on for many years.

The way people define space has been subject to many interpretations over the course of history. An approach rooted in western culture or dogma considers space as static and uninhabited, also called a mathematical space (Flynn, 2007). But the idea that space consists only of the visible is one of modern times. Descartes’ “res extensa” and “res cognitans” model for example, divides space into “the visible and the invisible, the physical and the realm of feelings, thoughts and spiritual experience” (Flynn, 2007). This distinction was almost completely gone around the year 1900, when the physical realm had become the sole identifier for space and place. This emphasis on materialism has led to a detachment of people from their surroundings. This reflected strongly in regard to city planning architecture; Pevsner (1981) calls the 21th century the century of the masses, where a shift from small communities to large urban landscapes called for a new sense of spatial order. Planners and designers thought this order could be achieved through architecture. One of the key elements of modernistic architecture typical for that time is coherence, and the idea that function is more important than form. This modernistic school of thought resulted in structures "born of a universal logic, and devoid of historical and regional references" (Ley, 1987).

The shortcomings of modernistic architecture proved that if something is designed as a place, it does not necessarily become a place. Something more than physical design is needed to distinguish a place, and to determine its effective "placeness". In an architectural context, space is not designed by merely physical objects, it is considered a combination of buildings, open space and contextual conditions. Norberg-Schulz' (2000) "Genius Loci" theory defines place as a "dynamic unity of architectural elements, inhabitants and interactions between/among them". A sense of place is therefore not just being surrounded by a spatial setting, but being engaged in a spatial setting.

Concluding

The concept of placeness and engagement in a spatial setting is relevant for the study area in the sense that augmented reality might stimulate this type of user engagement. It is therefore interesting to see how people experience the area before, and after using the Layar application. Is it the same? Or does the application change the perception of the area because it stimulates engagement of the users with their surroundings?

2.2 Visualization of digital heritage

On an abstract level, the only way people understand reality is through representations (Paraizo & Kós, 2007). These representations consist of selected elements to create "a partial and focused understanding of reality, given the complexity of real objects". According to Paraizo (et al. 2007) each person focusses on a different representation of the same object and even the same person represents it differently in distinct moments. When visualizing heritage objects, the same kind of mental and physical representations are constructed.

2.2.1. Digital heritage experience

While visiting ancient ruins or archaeological sites, a mental reconstruction of the historical situation requires a mental effort of the visitors (Cutri, Naccarato, & Pantano, 2008). Mental constructs rely heavily on the imagination of the visitors themselves, perhaps enabling them to make an even more truthful representation of the historical situation. At the same time, mental representations can also be highly romanticized and therefor unrealistic. Visual reconstruction of objects within a digital environment using images, models, audio or video enables the presentation of the same information without his kind of mental effort. This can allow visitors to have a more immersive experience, because the information or objects are more tangible compared to mental constructs. But there are two sides to this coin, because a visual presentation of virtual heritage can only provide a certain degree of realism, determined by technical limitations and the designer's preference.

According to Flynn (2007), mechanical or automated reproduction of heritage involves a "loss of aura" associated with cultural objects and a degradation of the traditional value of cultural heritage. It is argued that such a mechanical reproduction invokes a new form of perception, aimed at a predefined purpose for presentation and therefor reduces the scope of cultural values attached to such an object. One of the key issues here is that heritage constitutes more than just a physical object, and that a mechanical reproduction method can be considered too crude a way to realistically represent cultural values.

A large realistic 3D model of an object is sometimes considered the hallmark of authenticity (Flynn, 2007), but the reduction of a cultural heritage experience to a visual simulation disrupts its connection to material evidence. Interpretation of the object by the user replaces the experience of the past, and this separation from history can therefor erase "a sense of enchantment and wonder". This detachment of heritage from its location might be avoided when a medium such as augmented reality comes into play, where the users are presented with the models on their original location. The technical capabilities of the medium however, can limit the amount of visual detail or "realism" such a model might provide. Nevertheless, augmented reality might be a more suitable medium for communicating more than just a visual representation: a heritage experience.

Knowledge transfer can be more efficient by tying abstract information to tangible experiences. In the process of trying to create tangible virtualities, Milekic (2007) notes two shortcoming characteristics of a virtual environment. First, there is an absence of support for meaningful experiential interactions with virtual information. And second, the emphasis of the virtual environment is currently on quantity rather than quality of information. It is therefore argued that designers of virtual environments should meet two challenges arising from these shortcomings. One, a virtual environment should be able to support user interactions that contribute to information transfer and retention. Two, it should make the quality of virtually presented information meet or exceed a real-life experience.

Concluding

The type of visual reconstruction and amount of detail used depends on the object of communication. For communicating the architectural styles of specific buildings aimed at heritage experience, the manual construction of 3D models and presentation through augmented reality might therefore be most desirable.

2.2.2 Visualization approaches

The notion that visualization is a representation, and therefor highly subjective, implies that visual artists and cartographers possess important persuasive power (Sheppard, 2001). Different kinds of visualizations invoke different kinds of emotions, and relay different kinds of messages. Hence, each object of communication requires a unique visualization approach.

The choice for the level of detail or realism for instance, is a difficult one. An overemphasis on historically accurate representations might be at the cost of engagement types other than visualization, which can result in heritage devoid of cultural meaning (Flynn, 2007). Too realistically looking images can "pretend to be the actual truth though the actual historical situations are uncertain or unknown", and therefore be either misleading or unbelievable (de Boer, Breure, Spruit, & Voorbij, 2011). So instead of achieving visual realism, one could also look for the type of embodiment the user wants to attain, how authenticity or experience can be achieved or how these can be simulated. So besides visualization, it is also important to think about how virtual environments can contain feeling, perception and cultural context.

For this study, the object of visualization is a street of historical buildings. When it comes to urban modelling, several approaches are suggested:

Manual modelling

The most time-consuming approach is the use of manual modelling. This approach constitutes the design of an object by hand, manually drawing its shape and textures (Poullis & You, 2011). This enables a good control of detail, and therefor sense of authenticity. When recreating a specific historical object, this approach is preferred due to its high attainability of realism. An object with a greater level of detail contains more data; it requires more polygons, more colours and a higher resolution. Because this approach is so labour intensive it is not very practical for large areas or datasets, for which a suggested method is to combine both manual and automated modelling.

Automated modelling

Besides manual modelling, there are a number of methods available for rebuilding historical buildings, or even entire cities. One approach to automated 3D reconstruction for example, uses aerial imagery from different angles to extract buildings and streets (Parish & Müller, 2001). This method requires high-quality photographic materials as input, and could therefore be less suitable when reconstructing buildings from old source material. When reconstructing large areas or sites, 3D modelling can become quite a tiresome effort. A lot of research is therefore focused on efficient data management, fast real-time visualization and the optimization of memory usage.

Parish & Müller (2001) introduce a new form of procedural modelling with the development of a system called CityEngine. This system is capable of modelling a complete city while requiring only a small set of geographical and statistical data as input. Instead of using aerial pictures, the system uses a set of comprehensible rules to depict the location of roads and buildings. The first step for example, is to create a network of roads, after which the residual space is allotted for building plots (Figure 1).

FIGURE 1 ESRI CITYENGINE

The texturing of buildings is also done by a procedural approach: patterns such as brick walls and stone can be tiled, and elements such as windows and roofing are generated according to rule-based patterns. These kinds of techniques can generate a persuasive image of a cityscape, where buildings follow certain architectural styles attaining some sort of historic accuracy. The manual addition of certain landmarks can finally contribute to a high level of spatial identity.

Integration of manual and automated modelling

Computer games, both recreational and "serious gaming" applications often take place in a virtual urban setting. Not only fictional cities, but also existing or historical urban areas are reconstructed in order to provide a playground for the user (Bishop & Rohrmann, 2003). In the game series "Assassin's Creed" for example, historical cities such as Damascus, Jerusalem, Firenze (Figure 2), Venice, Rome and Constantinople have been brought to life using state of the art 3D modelling techniques and a smart combination of reconstructed historical landmarks and generic streets using a historical building style (Tutenel, Smelik, Lopes, de Kraker, & Bidarra, 2011). The modelling of such environments can be very time consuming, depending on the modelling approach that is taken. Each type of digital landscape requires a different approach, and therefore has its own set of considerations regarding the balance of manual and automated modelling.

Tour into the Picture

FIGURE 2 ASSASSINS CREED II: FLORENCE

An entirely different technique is Tour into the Picture (TIP). This technique "maps a terrestrial photograph onto a spidery mesh that defines the perspective for that particular photograph" (Horry, Anjyo, & Arai, 1997). Rather than creating a full-fledged 3D environment, TIP is a technique aimed at imitating a 3D environment by using billboards and 3D polygons, creating the illusion of 3D. One could call it 2,5 D. This technique was used by the TU Delft to create a 3D "flythrough" of the city of Delft around the 17th century, based on paintings by the famous painter Vermeer (Walking with Vermeer, 2001).

The source images need to be in high resolution in order to sufficiently support zooming, because when extreme texture stretching is applied the danger of pixilation is imminent. The images also have to contain a large depth of field, so that every object is in focus. The biggest limitation of this technique is therefore that not every image is suitable, especially when using historical black and white photographs. The usage of photographs instead of 3D models overcomes the problem of lack of detail or authenticity related to the construction of abstract 3D models. It helps to "understand the scale of the environment itself, as well as the spatial relations of elements presented in the photograph" (Horry, Anjyo, & Arai, 1997). It is much less labour intensive than creating a detailed 3D model by hand.

Concluding

The modelling approach, just like any visualization method, depends heavily on the object and process that needs to be presented. For this research, the object consists of a number of buildings that were unique for their time and location which makes the automated approach irrelevant. High quality photographic material is available, however not for every building, which makes the TIP method unsuitable for this case study. Instead, the manual modelling approach is used.

2.3 Augmented Reality

Visualization requires a medium of communication. For this research, the possibilities for communicating cultural heritage through mobile augmented reality are researched.

2.3.1 Virtual heritage projects

In the field of virtual heritage, augmented reality is used to enhance the overall experience of the visitor of a heritage site. An interactive and realistic AR system can enhance, stimulate and motivate people's understanding of certain events (Wojciechowski, Walczak, White, & Cellary, 2004). A system like "archeoguide" for instance, offers a personalized electronic guide and tour assistant for heritage sites. This is a comprehensive system which uses special augmented reality glasses to guide people along a certain route, displaying information and 3D simulations of artefacts at certain locations. With the rise of mobile augmented reality on smartphones the idea of an audio-visual augmented reality tour has become more tangible and accessible.

The SCULPTEUR project, which stands for *Semantic and content-based multimedia exploitation for European benefit,* constitutes a solution for museums to create and manipulate digital representations of museum objects. SCULPTEUR uses 3D silhouette techniques in order to create 3D objects reconstructed from the museums database in combination with other multimedia data. Museums can therefor build interactive learning scenarios, which can transform visitors from passive viewers and readers into active actors and players. In the latter case, the learning process is much more effective.

The 3D Murale project, *3D Measurement and Virtual Reconstruction of Ancient Lost Worlds of Europe,* is a professional tool for archaeologists capable of recording archaeology excavation phases using Virtual Reality techniques. Because the physical state of the excavation site is recorded at different phases of the excavation, this enables the researchers to revisit these physical states after the excavation is finished.

The options for making virtual heritage more interactive are very rich. An example of such a participatory system is the Virtual Dig Experience installed in the Seattle Art Museum. This system uses virtual reality and augmented reality techniques which enables visitors, particularly children, to discover artefacts for themselves following a trail of augmented clues.

Concluding

Different kinds of virtual and augmented reality applications have made their way into the field of digital heritage. The key characteristics for these projects have been interactivity and usability. Easily accessible and adaptable systems have proven to have high educational value. Since the key to improving heritage awareness is to communicate, digital heritage through augmented reality seems a promising technique.

2.3.2 Basic principles and techniques

According to Bimber and Raskar (2005) a "correct and consistent registration between synthetic augmentations (usually three-dimensional graphical elements) and the real environment is one of the most important tasks for augmented reality". In order to attain an accurate registration the system needs to be able to constantly determine the users' position within the environment. One of the top priorities in the research field is therefor to improve the precision and performance of the *tracking systems*. For outdoor environments, a Global Positioning System (GPS) is used, in combination with gyroscopes and accelerometers. This is comparable to what modern mobile smartphones use; GPS, gyroscope and digital compass.

These tracking options are however not without issues. GPS can attain a good accuracy in large open areas, but when used in urban areas its performance drops dramatically (Schall, et al., 2009). Alternative tracking methods are visual, or feature based tracking. Phones can use a feature database, where the camera is able to recognize certain objects in the phone's field of view. By attributing positions to these objects, the relative position of the phone can be determined. Visual, but also locational markers can be used to trigger augmented reality content when the handheld device is in the required vicinity or has the marker in its camera view. The accuracy of the magnetic compass can be distorted by nearby industrial installations or general infrastructure causing problems with angular orientation of the device.

Besides tracking, another important factor in augmented reality is *display technology*. Bimber and Raskar (2005) distinguish three main display classes: head-attached, hand-held and spatial displays. *Head-attached* display devices consist of special helmet outfits, or special glasses, such as the recent Google augmented reality glasses prototype "project glass" (Baldwin, 2012). These kind of devices are hands-free, and can "see what the user sees", thus functioning as a digital extension of the user's vision. *Hand-held* devices such as PDA's or smartphones require the user to point the device's camera at a point of interest by hand. *Spatial displays* detach the technology from the user and integrate it into the environment. It uses static display screens that are spatially aligned with the environment, "a window on the world" so to speak.

These different technologies each have different advantages and disadvantages. Head-attached and hand-held displays can be used in mobile situations, while spatial displays cannot. Spatial displays however can provide higher quality graphics and thus a better sense of realism because of its static nature; the hardware does not have to be compressed into a mobile device.

A third basic factor is *real-time rendering*. One of the most important goals of augmented reality is a seamless integration of graphical objects with the real environment to such an extent that the virtual is very difficult to distinguish from the real. If objects for example would have the option to cast shadows and reflect light, the digital content might appear much more natural. The manner in which the virtual content behaves in the real environment is therefore key to the augmented reality experience.

2.3.2 OPERATING DEVICES

When it comes to mobile augmented reality there are three major applications which can be used: Junaio, Wikitude and Layar (van der Mijden, 2011). The first is primarily marker-based instead of GPS, using for instance QR-codes to trigger POI information. Junaio does support a lot of visual options and seems to be user-friendly on the developers' side, but has not yet refined the way it handles 3D objects. Wikitude supports a lot of user input; people can add their own POI's with information. However GPS based, Wikitude does not yet support 3D objects. In order to present 3D objects in a user-friendly digital environment the most obvious application for this study is Layar.

Layar

The Layar application consists of a publishing environment, a content browser and a content player (Wang, 2011). The created layers are stored in the publishing environment and made available to the public through the Layar server. In this environment static data for the layer is stored, such as the look and feel of the interface, listing details of the content and the URL for the service provider. The layer itself consists of a programming script, which can be created using a wide variety of programming languages such as PHP, Java or MySQL as long as the response of the layer service provider is in JSON format. The data communicated through the application is based on third-party services. In order to create a layer, a layer service needs to be created that can deliver POI (Points of Interests) content (GPS locations) to the layer server and publishing environment. Two basic components are needed for this service: a database (layer content source) with the data and a public web server. The architecture of the Layar app is visualized in Figure 3)

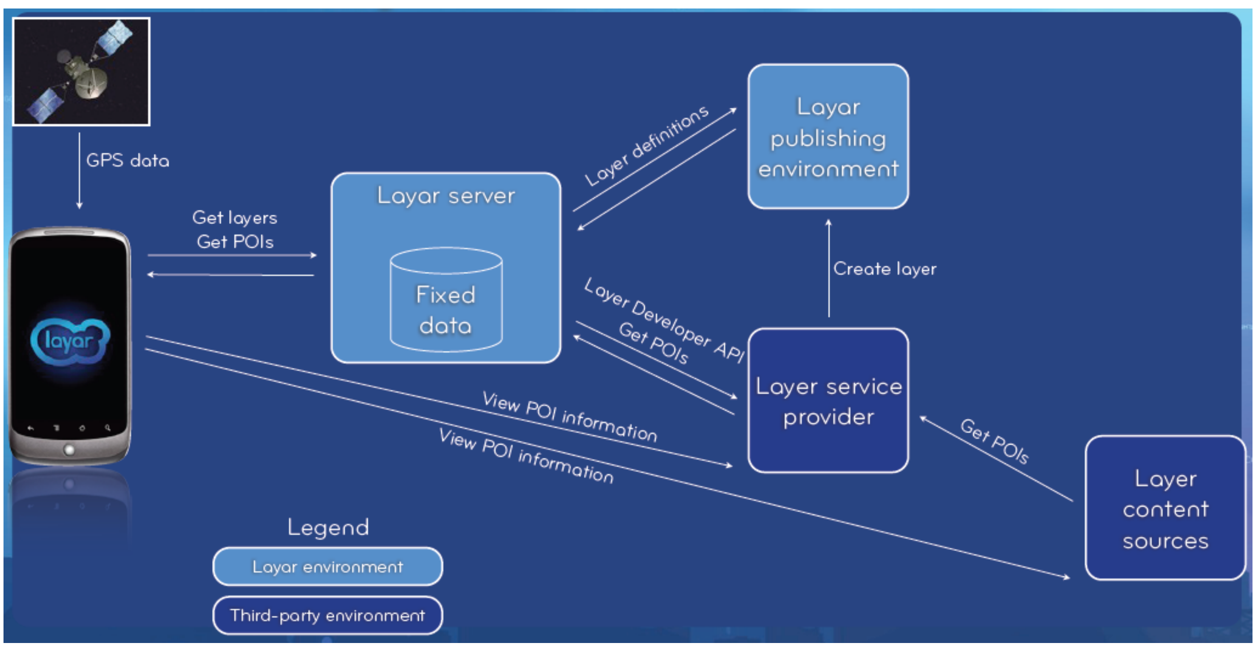


FIGURE 3 ARCHITECTURE OF THE LAYAR APPLICATION (WANG, 2011)

Multiple content formats are supported, such as images, icons or 3D models. Connections with other forms of social media such as Facebook and Twitter are also easily established. Interactive elements can also be integrated, such as audio, video, calling and email options. The application is therefore not necessarily limited to the mere positioning of spatial objects in space. For example, the use of a video of a 3D fly-through of the location or the addition of informative text fields is also a possibility. Especially the addition of an audio function can contribute to an immersive experience of the Layar content.

PorPOIse

For the Nijmegen prototype a layar server hosted by the WUR called PorPOIse is used. PorPOIse is an open source layar server, which transforms POI data taken from an XML document or MySQL database into a JSON response format automatically (PorPOIse, 2012). The layer content, such as images, 3D models and audio files is stored at a publically accessible WUR server.

Layar Vision

A new feature in Layar is Layar Vision, a visual based tracking feature (Layar, 2012). The application registers the phone's camera image and scans it for a so-called visual fingerprint. This works best on unique objects like logo's or drawings. The developer can then place augmented content over the visual fingerprint, such as photographs or 3D objects. Because this feature does not use GPS to identify points of interest, its accuracy is solely dependent on the quality of the camera image and lighting conditions. The usefulness of this feature for the tracking of the case study area is questionable, because there are no specific visual markers in the "real world" for each historical building model, making the positioning of those buildings very difficult. Moreover, the ability of Layar Vision to register and track large objects like entire buildings is not yet known, but would be interesting to try for future research.

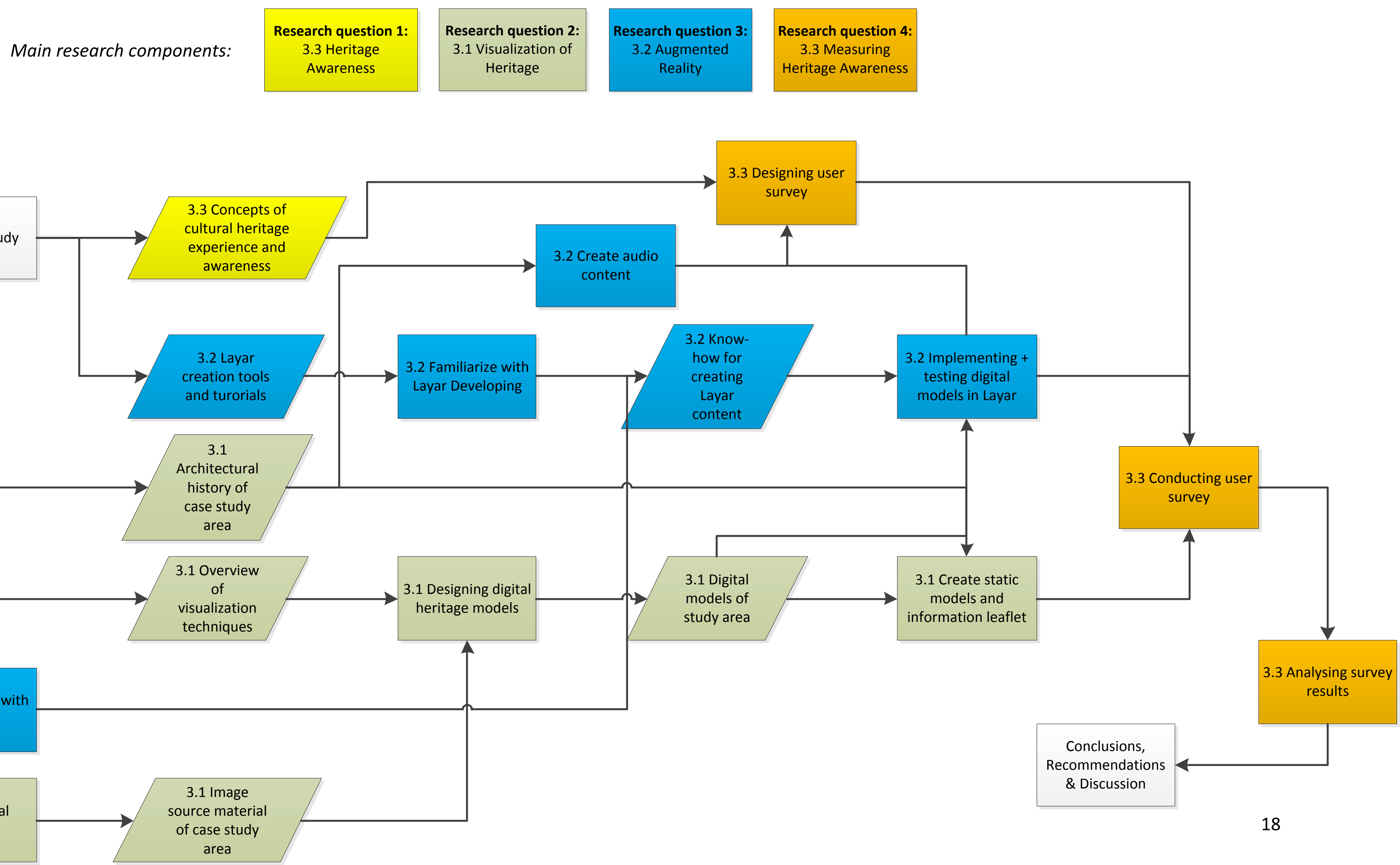
Concluding

For this study, the most effective augmented reality system is Layar due to its capabilities for handling 3D models and sound, as well as its user friendly interface and developer options. Visual tracking with Layar Vision looks promising, but its usability for recognizing and project buildings is not yet been tested, therefore the "traditional" approach of GPS-based tracking is used.

CHAPTER 3 METHODOLOGY

This chapter describes the research methodology for each of the four components of this study; digital visualization of heritage, implementation in the augmented reality application, heritage awareness and measurement of heritage awareness.

The research design methodology for this thesis study is visualized in the following schematic.



3.1 VISUALIZING VIRTUAL HERITAGE

The first step is to make digital representations of the “disappeared” cultural heritage situated in the case study area, which is “de Grote Markt” in Nijmegen, the Netherlands. The visual characteristics of the digital models are based on literature dealing with digital representation; what needs to be communicated, and which level of detail is desired in order to do so? The visualization types vary in amount of detail, sense of realism and method of presentation. This enables a comparison of 2D vs. 3D, static vs., dynamic, photo-realistic vs. schematic and possibilities for sound and text. The case study objects are visualized for only one period in time. Because multiple visual models have to be designed, it would take too much time to do this for multiple time periods. The scope of this research is therefore limited to the perception of different types of visualization techniques, not the perception of multi-temporal heritage representations.

3.1.1 CASE STUDY AREA

This medieval square is situated in the heart of the city centre, and well known for its characteristic monuments such as “de Boterwaag” and “het Sint-Stevenspoortje” (see Figure 4). A large part of the historic square was destroyed due to the bombing of the city in 1944, causing the square to lose some of its historical value. Because augmented reality enables us to make the invisible visible, digital models of the buildings that were destroyed can be used to recreate the architectural situation of the square circa 1935. By emphasizing the cultural heritage that is no longer visible, the awareness of the area as a historical location might be improved. The awareness constitutes the change of architectural style and topographical layout.

FIGURE 4 ST. STEVENSPOORT, NIJMEGEN

The city of Nijmegen promotes itself as the oldest city of the Netherlands and the square is a symbol for the city’s historical image. With the disappearance of the western wall in 1944, the municipality decided to rebuild this part of the square in the at that time popular modernistic style (Tummers, 1994) (see Figure 5). This type of architecture is characterized by an emphasis on function instead of form. Time and money were pressing issues, leading to a rapid reconstruction of the city centre without taking into account the location’s historical aesthetics. Although a lot of the historical street plan was retained, the layout of the western square wall was altered. The Augustijnenstraat was situated further to the north-west, which gave the square a more secluded character contrary to the wide and busy street the Augustijnenstraat is now. Also, instead of the solid wall of buildings it is today, there was a mall alleyway in the middle, the Scheidemakersgas. These changes in architectural styles and the square’s layout can be presented with augmented reality using digital models of the historical situation.

FIGURE 5 POST-WAR ARCHITECTURE HEMA, NIJMEGEN

De Grote Markt, being one the most important locations in the city, has been well documented throughout the years. This has resulted it a good availability of source material, such as photographs, blueprints and sketches of the physical situation before the 2nd world war. Another practical advantage of this location is the fact that the square is a large open area, which has an expected positive influence on the GPS accuracy of mobile devices such as smartphones.

3.1.2 Model characteristics

Any visualization, be it a map, painting or digital model, is guided by its own purpose. The message the creator or artist wants to communicate determines how a visualization takes shape. Hence, the digital models should be in league with their intended purpose. The goal of the visualizations in this study is to communicate historical architectural knowledge in order to improve the awareness of this knowledge. Two main characteristics of the demolished buildings have to be presented to the user visually: the buildings' locations and the buildings' architectural styles, including building façade details and masonry. 3D models of the historic buildings in the case study area are created using software such as Google Sketchup, while 2D models, such as black and white billboards of the street, can be designed using Adobe Photoshop.

Model dimensions

Because the models are projected using augmented reality the historical locations of the buildings have to be precise. The model dimensions and proportions therefore need to be true to the original structures. As a starting point, the historical cadastral map (Appendix I Historical Parcel Map) was used to determine the width of the buildings. Based on dimensions from several blueprints of the buildings the height was determined. By comparing buildings with known dimensions to buildings adjacent to these visible in historical photographs, the height of the remaining buildings was estimated. These dimensions are loaded into Google Sketchup for the creation of 2D and 3D models.

Modelling types

The subject of communication is architectural style. This constitutes the use of specific shapes, building materials and colours. Using old black and white photographs the building facades are duplicated in 3D, enabling the extrusion of certain architectural details as well as doors, window frames and shop displays. The building materials and colours are identified using literature describing the pre-war architecture in Nijmegen (Meijel & Tummers, 2006) (Dongelmans, 1989) as well as the study area itself. Some of the buildings are designed by an architect who created similar designs in Nijmegen which serve as a reference point for building materials and texture colour.

Besides 3D models, the entire block of buildings is also visualized using historical photographs of the building facades. These pictures are used as billboards, acting like a 3D object using the photographs as textures. This way the perspective and point of view behaves like a 3D object, providing the impression of real buildings instead of just a static picture. In order to highlight certain architectural details, some excerpts of the black and white photographs are used for zooming in on certain details. These shapes are too complicated to duplicate in 3D, and therefore better visible in a photograph than in a comprehensive 3D model.

The result of this research step is three types of digital models: photo-realistic 2D images of entire buildings, schematic 3D models and photographic close-ups of architectural details which are presented using mobile augmented reality and a hard copy printed leaflet.

3.2 Augmented Reality Implementation

In order to research the possibilities for communicating cultural heritage through augmented reality, several digital heritage models are implemented using the Layar application. Layar is a user-friendly software application for smartphones that supports the development of data layers which can be overlaid on the camera view of a smartphone. For this implementation a special “layer” is developed containing the simulated heritage models.

The implementation of mobile augmented reality can be considered as the technical part of this research, as the creation of Layar content requires a moderate amount of programming. Placing the heritage models within the software as well as establishing a connection with the Layar server leads to some trial & error in order to achieve the desired functionality of the application. The Layar development community offers advanced tutorials through which one can familiarize himself with the software. An expert on this topic, Aldo Bergsma from the Wageningen University, is also consulted to assist in this part of the research. Besides the visual models, additional information is provided using the audio function of Layar. This function enables an audio-visual tour on the architectural history of the Grote Markt.

The technique of augmented reality is based on three main principles: tracking, display technology and rendering of content. Because Layar is a mobile augmented reality application that runs on a smartphone, the tracking is based on the phone’s GPS reception, the display is hand-held, and the ability to render objects is limited by the graphical capabilities and network bandwidth of the smartphone. The hand-held device used for this study is the HTC Desire (see Figure 6). The most important technical specifications of the hand-held device are as follows:

Display:

- 9.4 cm diameter
- 480 x 800 pixels

1 GHz Scorpion CPU

3G (7.2 mbps) internet connection

FIGURE 6 HTC DESIRE SMARTPHONE

The display and graphics processor do not support the High Definition format. The screen of the device is also quote small, limiting the field of view. The amount of model detail that can be displayed is therefore very limited. The Layar application requires that the visual content, such as the photographs and 3D models, is loaded from an independent server via internet connection. The data size of the models is therefor also important, for long loading times might influence the heritage experience in a negative way. These limitations are taken into consideration while designing the models.

The two challenges identified by Milekic (2007), attaining interactivity and real-life experience visualization, are not easy to meet with the mobile augmented reality format. Especially the visualization part requires significant computation power not possible with current smartphone devices. Interaction can only be achieved to a certain degree; people are able to navigate through the different visualizations themselves, but the most interactive part is the fact that people can walk around the area and view the 3D models from any perspective that they’d like. They are not bound to the field of view from a single location, but are free to view the buildings just like they would in real life. So even though the visualization might not be very “real”, the way people can view these buildings might speak to some sense of a real-life experience.

Besides visual communication, augmented reality also supports auditory communication. The user of the application is guided through the application's content via an audio tour, where the architectural styles and characteristics of the buildings are explained. This enables the presentation of exactly the same factual information as the paper leaflet.

The result of this step is a Layar prototype layer with the digital models and audio tour as content, which is presented and actively used during a user survey aimed at measuring the communication of architectonical information and heritage awareness.

3.3 Heritage awareness

What constitutes heritage awareness? How do people experience and perceive heritage, simulated and real? These are questions that have to be answered. A literature study is therefore conducted on the topic of cultural heritage experience, perception and interaction design. This part of the research results in an overview of theoretic constructs on the user experience of cultural heritage and the concepts of embodied experiences and phenomenological knowledge formation. The focus lies on the way people perceive space in relation to cultural objects and artefacts, and how the interaction between technology and users within this subject takes shape.

This field of research is very broad, and can only be implemented in this study to a certain degree. The most important goal is to construct a framework of ideas and possibilities for the use of augmented reality as an awareness communicator. The focus lies on the characteristic user experience of mobile augmented reality, and how this medium might be more, or less, suitable to communicate awareness.

3.3.1 Measuring awareness

In order to measure the effect of mobile augmented reality on awareness of cultural heritage, a user survey is conducted (Appendices VI – IX). The survey content is derived from literature on the research of knowledge formation, user experience and awareness through digital media. The goal of this survey is to communicate a story about the architectural history of the "Grote Markt" before, and after the bombing of the city in 1944 (See Appendix II Architectural story (in Dutch)). The "heritage" used in this research therefore consists of the following:

- Topology of the area (location of the buildings circa 1940)
- Architectural styles and details of the historical buildings
- The historical experience of the area

These topics cover both the object (the buildings and architectural styles) and process (difference in architectural style) of the case study area.

This story is told using Layar, a mobile augmented reality application for Android smartphones and iPhones. Using an integrated audio feature, the participant is presented with architectural information and guided through different visualizations of the demolished buildings of the case study area (See Appendix III Instructions for AR Application).

In order to research the difference in awareness attained by augmented reality, the survey group is divided into two groups:

- A group that will use the Layar application
- A group that will use a printed leaflet containing the same information

This survey therefore consists of two different types: the first a tour with the use of an interactive audio-visual augmented reality application on a smartphone, the second a printed folder with the same information.

Survey content

The survey contains the following information:

- The perception of the case study area (topology, cultural values)
- The increase in architectural knowledge
- The evaluation of the different visualization types
- The practical usability of the format (augmented reality)

Inspired by the archeoguide principle, in the case of the augmented reality application, this information is presented to the user through a guided audio tour and by superimposing 2D and 3D models of the buildings on the camera view of the device. Architectural information, like building styles and details, will therefore be presented visually but is also explained using the audio function of the application. A couple of the historical buildings will be highlighted. These buildings were chosen because they are a good representation of the architectural styles typical for that time, such as Art Nouveau, Art Deco, Neo-renaissance and Neo-classicism. The printed folder contains the same information in text format, presented in the same order. The same models are presented with illustrations and screenshots of the 3D models and black & white photographs.

Besides two different formats, the user will also be presented with two different surveys, a pre-survey and a post-survey. Because the goal of this survey is to determine a *change* in knowledge, experience and perception, a baseline has to be established before the presentation of the architectural information. During the pre-survey, the user is asked to answer a couple of questions about their architectural knowledge, how they view the case study area and whether or not they have had any previous experience with augmented reality.

After the users have completed the tour, be it by using the augmented reality application or the printed folder, they are asked to fill in another survey. The participants are asked about certain global, but also detailed information presented to them during the tour. For instance, people are asked about the topology of the area by drawing a map of the buildings from memory. This might provide some insight into which format and visualization style influences knowledge production as well as spatial perception.

User group

In regard to the user group, a number of considerations are made. For instance, the user survey covers three main topics: the formation of knowledge through digital heritage visualization, the awareness or experience of the case study area as a whole and the usability of the AR format. The user survey is quite intensive, requiring a detailed hands-on approach. The number of time required for each participant is therefore high, limiting the number of participants to 15-20 people.

The target group, people with an affinity for cultural history and preferably experience with modern mobile applications, is largely gathered from my personal network of heritage enthusiasts living in the area of Nijmegen. This assures a sufficient amount of participants, improve participation as well as enable a thorough reflection on the survey content.

3.3.2 Expectations

Based on the theory on augmented reality and heritage experience a number of hypotheses are formulated:

Compared to users of the folder guided tour, people using the AR application:

- Will remember more spatial information: where the buildings were located.

Because the format of augmented reality requires the user to look at the location of a specific building, by aiming the device towards the spatial content, the user can make a better spatial connection and form a mental map (Wallet, Sauzéon, Pala, Larrue, Xia, & N'Kaoua, 2011) of the building information and the study area.

- Will experience a bigger change in area perception towards historical location.

Based on the theory on augmented reality and immersive experience (Portales, Lerma, & Perez, 2009) (Refsland, Tuters, & Cooley, 2007), the format will cause people to move around more freely, walking towards and away from the building models, possibly giving them a more complete experience of the area instead of standing still with a leaflet or folder.

- Will evaluate/rate the 3D models better.

The added value of the 3D models will be most visible using a 3D environment because people are able to walk around the object and therefor interact with the 3D features (Bellotti, Berta, Cardona, & De Gloria, 2011) (Keating, Guest, Konertz, Padovani, & Villa, 2011). The illustrations in the leaflet lack these qualities, although the colour and building materials remain visible.

Compared to users of the AR guided tour, people using the leaflet:

- Will remember more factual information (building styles, details).

When people are reading the folder, they are not distracted by the visual augmentation; the preoccupation of positioning a hand-held device and walking around the area at the same time (Bimber & Raskar, 2005). This might enable them to absorb the factual information better, but lead to a lack of spatial knowledge formation.

- Will evaluate black and white photographs better

Because the 3D features will be lost on the 2D presentation of the folder, people might find the black and white photographs more “authentic” (de Boer, Voorbij, & Breure, Towards a 3D Visualization Interface for Cultural Landscapes and Heritage Information, 2009).

3.3.3 SURVEY OUTCOME ANALYSIS

In order to determine whether these hypotheses are correct the questionnaire outcome is analysed in SPSS. Most of the questions concern the commonly used (Dawes, 2008) 5 point Likert scale; a relative degree of appreciation such as: “never, rarely, sometimes, often, always”. These outcomes are noted as a value between 1 and 5. Because the results consist of mainly ordinal data, the Spearman’s Rho correlation coefficient method is used to see if and in what way the different variables are related; such as medium, change in historical experience, evaluation of visualization types etc.

Topographical knowledge

For analysing the topographical knowledge of the users one of the most important factors is the small alleyway “Scheidemakersgas” which was situated more or less in the middle of the building block. The second point of interest is the location of the “Augustijnenstraat”, which marks the end of the right hand side of the building block and was situated further to the west. The participants are also asked to name the buildings they’ve drawn, in order to see if they are placed in the correct order.

When analysing the resulting maps drawn by the users, a score system with the criteria described in Table 1 is used:

TABLE 1 TOPOGRAPHICAL KNOWLEDGE CRITERIA AND SCORE.

Criteria	**Score**
Did the user draw the “Scheidemakersgas”?	
Yes	1
No	0
Did the user place the Augustijnestraat further to the right?	
Yes	1
No	0
Number of buildings placed in the correct order left-right.	
1-2 buildings	1
3-4 buildings	2
The absolute location of the buildings.	
Within buffer of 0 – 1 grid cells	1
Within buffer of 2 – 3 grid cells	0.5
Outside buffer of 4 grid cells	0
Total Topography Score	**Sum**

The absolute location of the buildings is measured manually using a grid overlay of 1 x 1 cm (See Appendix X Survey results Topography, Figure 43 & 44). Because this variable is highly dependent on the user’s ability to draw and read maps, the weights are relatively low. For each respondent, the scores of Table 1 are summarized into the *total topography score*. The total score is then correlated with the change of the medium to see if there is a significant relation.

Architectural knowledge

Besides topological knowledge, the tour also includes a lot of detailed information about the architectural styles of the historic buildings. Before taking the tour, the participants are asked to answer questions about these topics in order to establish a knowledge baseline. For instance, people are asked to assess their own knowledge on architectural history of the Netherlands as a whole, and the case study area in particular. In order to verify this, they were also asked to list a number of important architects and building styles to see if their assessment is somewhat reliable. The results of the specific questions on architects and styles are afterwards compared to similar questions the participants were asked to answer after the tour to see if their knowledge on the topic has increased.

The questions after the tour are interpreted as the criteria described in Table 2 and Table 3:

TABLE 2 ARCHITECTURAL BASELINE KNOWLEDGE CRITERIA AND SCORE

Criteria	**Score**
Number of architects important for Nijmegen	[0…5]
Number of architectural styles significant in the Nijmegen area	[0…5]
Total baseline score	Sum

TABLE 3 ARCHITECTURAL KNOWLEDGE CRITERIA AND SCORE.

Criteria	**Score**
The recollection of the most important architect of the case study area	
Yes	1
No	0
Recollection of number of buildings designed by this architect	[0…7]
Recollection number of architectural styles present in the case study area.	[0…5]
Recollection which building was built in which style	[0…5]
Recollection which details/characteristics belong to which style.	[0…15]
No. of styles ordered in the correct timeline	[0…5]
Total knowledge score	Sum

Equation 1: $$\frac{Total\ knowledge\ score}{(Total\ baseline\ score + 1)} = Corrected\ knowledge\ score$$

The baseline of knowledge is used to correct the final architectural knowledge score. By doing this, more weight is attributed to the gained knowledge of participants with a low base level of knowledge but a high result, than to gained knowledge of people with a high knowledge baseline. In order to do so, the total baseline score (+1) is divided by the total post-tour knowledge score: if the baseline is high, the resulting value will be lower compared to when the baseline is low (Equation 1). The "+1" is for the case the initial baseline score is 0. The resulting value, referred to as the "*corrected knowledge score*", is an increase in architectural knowledge corrected for the original knowledge baseline of the user. The corrected score, as well as the individual components (or questions) are once again correlated with the medium to see if the correction leads to both a higher correlation and a higher significance.

Perception of the area

When it comes to the perception of the case study area, participants are asked to write down to what degree they view the area as a shopping area, nightlife area (bars, clubs), connecting road (traffic; busses; cars) or historical location on a scale of 1 to 5. After the AR or leaflet guided tour, the participants are asked to write down their degree of perception again. The result is a changed or constant value of perception, which is correlated with the medium type to see if there is a significant relation.

Evaluation of visualization styles

Both survey groups are presented with the same black and white photographs of the entire building block, coloured 3D models of certain buildings and close-ups of the high resolution black and white photos in order to highlight certain architectural details. After the tour, the participants are asked to rate these visualization styles on a scale of 1 to 5, as well as provide additional feedback on the models.

Concluding

Whether or not the goal of “raised awareness” is achieved is difficult to determine. But awareness is about knowledge communication, so if the user’s experience of the area changes significantly to “historical location” and the user’s knowledge of architectural history improves, this method of heritage communication might provide new opportunities for communicating digital heritage and improving awareness.

CHAPTER 4 VISUAL MODELLING RESULTS

This chapter describes the modelling results of this study; the preparation of source material, the creation of building models, audio tour and the implementation of the content In Layar.

4.1 SOURCE DATA

In order to get an idea of the architectural situation of the Grote Markt around 1935, the first step was to perform a preliminary search on black and white photographs of the area in the digital archives (beeldbank) of the Regionaal Archief Nijmegen (RAN). Based on this inventory, a number of high quality images of the faces of the buildings was requested, and supplied by the archives in .tiff format. These images served as the primary starting point for the 3D models. The quality of the photographs differed, some because of the angle in which the photo was taken, others because of the format or medium on which it was stored. For instance, one image derived from a glass negative was supplied with a very high resolution not that far removed from modern day digital photographs (Figure 7). Others, scanned from a book or postcard, were of considerable less quality (Figure 8).

FIGURE 7 GLASS NEGATIVE SCAN

FIGURE 8 NORMAL PHOTOGRAPH SCAN

Beside photographs, the RAN could also supply a select number of blueprints for some of the buildings around that time, which helped to supplement the photographs for parts of buildings that were badly visible. These blueprints were archived according to the corresponding building permits, which were documented from late 19th century and onwards. Blueprints were therefor only available for buildings which had undergone big changes during this period, unfortunately not for the buildings that were constructed during this period.

Beside visual source material, spatial data was also required. It was important to find out on which parcel or plot the buildings were situated, and how these parcels are to be compared to the current situation. A land register map with a detailed view of the parcels in 1940 was acquired through Hans Giesbertz from Het Kwartier van Nijmegen, an organization specialized in historic cartography of the Nijmegen area. The map was supplied in PDF format, and consisted of a scan of the original hand-drawn parcel map. This map needed to be geo-referenced to a current land register map, based on buildings that are still present, such as the St Stevens church, city hall, etc. The referenced map was then taken as a starting point for the situation and spatial dimensions of the models.

A comparison between the 1940 parcel map, the 2007 parcel map and the photographs of the street, as well as individual building faces, resulted in the following building map (See also Appendix I Historical Parcel Map):

FIGURE 9 2004 PARCEL MAP OVERLAID PARTLY WITH HISTORICAL 1939 PARCEL MAP

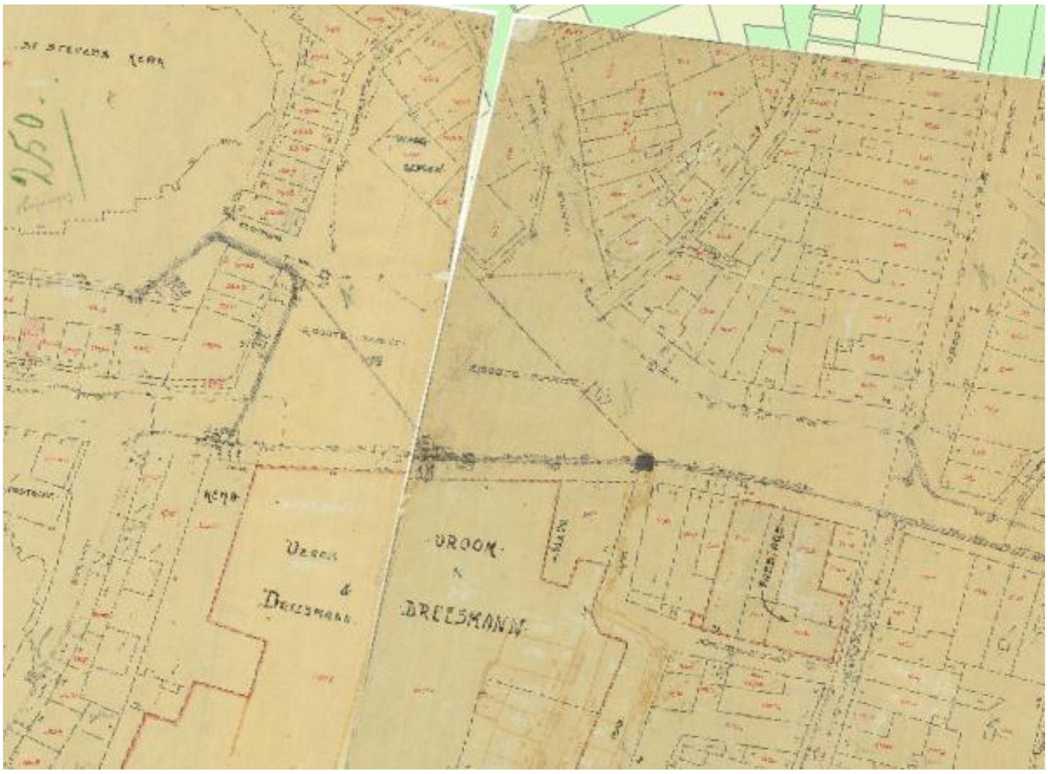


FIGURE 10 GEOREFERENCED 1939 PARCEL MAP

4.2 Building modelling

Using the map of Figure 10 as a starting point, two types of models were created: 2D collages of the black & white photographs used as billboards and hand-drawn 3D models.

4.2.1 Photographs

A lot of the acquired images offered a fairly complete record of the historical buildings. However, some of the photographs were incomplete, parts of the buildings were not present in the photograph and therefore had to be adjusted. On some photographs parts of buildings were compiled from different photographs, or parts of the building were duplicated strategically. In the case of the main Vroom & Dreesmann building (Figure 11), the perspective was "neutralized" using the manual skewing function of Adobe Photoshop in order to achieve the illusion of a front side perspective. For every image, the buildings were isolated by selecting borders and perspective lines, after which the image is "straightened" (Arnhem3D, 2010). Subsequently the left part of the roof of the V&D building was duplicated, inverted and added to the right side part of the roof. Finally, the grey colour values were adjusted to fit the rest of the building (Figure 12).

FIGURE 11 ORIGINAL PHOTOGRAPH

FIGURE 12 SKEWED AND CORRECTED IMAGE

Other buildings, such as those in Figure 13, Figure 15 and Figure 14 had to be compiled from different images in order to present a more complete view. This image was also less suitable for skewing, because there was too much perspective visible due to an overhanging building extension.

FIGURE 14 ORIGINAL IMAGE

FIGURE 15 SKEWED IMAGE

FIGURE 13 COMPILED IMAGE

This process was done for the entire block of buildings with various results. The overall result does however give a good impression of the street view circa 1935 (Figure 16).

FIGURE 16 HISTORICAL VIEW OF THE STUDY AREA BUILDING BLOCK.

Besides the overview of the entire block, some significant architectural details were extracted from the high resolution photographs and used as a close-up view within Layar (Figure 17). These images were added as separate POI's, which are displayed simultaneously next to the corresponding 3D models.

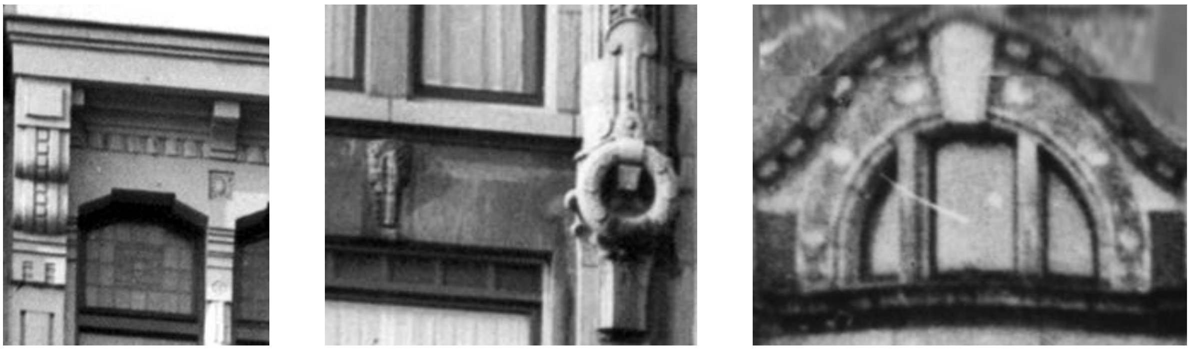


FIGURE 17 ARCHITECTURAL DETAILS

4.2.2 3D MODELS

In order to present more detailed architectural characteristics a couple of buildings were also modelled in 3D using Google Sketchup. The original idea was to model all the buildings of the western wall of the square, but time restrictions limited the amount of models to the right hand side part of the building block.

For most of the buildings, the b/w photographs were sufficient to create a detailed 3D model of the buildings. The criteria used were building completeness and image quality (sharpness, level of detail). The blueprints were used when the photograph was not clear enough, or when a part of the building was not on any of the available images. In the case of the van Dijk & Witte building no photographic material was available for the left side of the building, the part that was visible in the nearby alley, the Scheidemakersgas. Fortunately there was a detailed architectural drawing available (Figure 20) for the side of the building which still allowed a detailed reconstruction in 3D (Figure 21).

Some significant details, such as the old HEMA logo, were extracted from the photographs (Figure 18) and then hand-drawn in Google Sketchup (Figure 19).

FIGURE 18 OLD HEMA LOGO.

FIGURE 19 HEMA LOGO IN 3D MODEL.

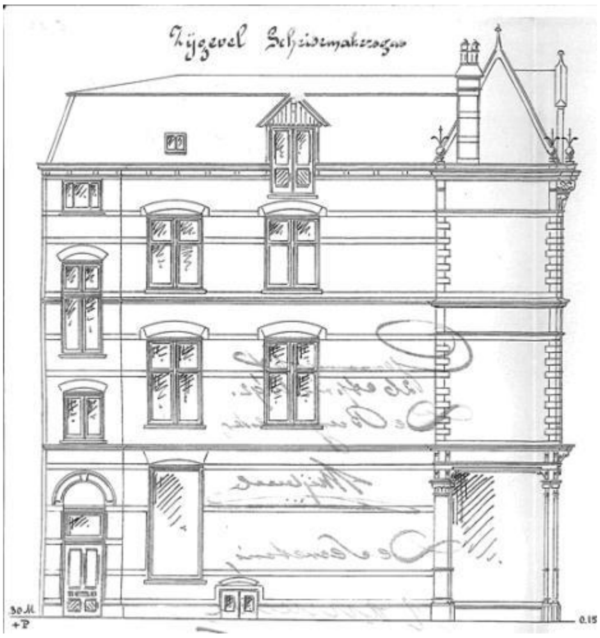


FIGURE 20 BUILDING SCEMATIC OF " VAN DIJK EN WITTE".

FIGURE 21 3D MODEL OF " VAN DIJK EN WITTE".

Findings:

The balance between the level of detail and the model size generated by the amount of polygons is quite sensitive. When using a tool such as extrusion, the extrusion of 1 face can lead to 2 to 4 more polygons, effectively tripling the model's size. When converting these models to Layar objects, triangulation takes place: every polygon is divided into triangles, once again doubling the model's size.

It is therefore suggested to add detail by using textures. A texture of building elements, such as windows, doors, window sills etc. taken from photographic source material can greatly reduce the model size. Even though a greater feeling of authenticity might be attained by draping those textures over the model, the model will contain less 3D features, and might be less visually appealing. An important prerequisite is however the availability of such (high resolution) photographic material. In the case of de Grote Markt, such material was not available.

For reducing loading times and graphic processing, Layar suggests a maximum model size of 1 MB, and 10000 polygons, therefor limiting the level of detail. When constructing several objects that need to be placed next to each other, loading times increase and the frame rate achieved on the mobile device drops dramatically. In order to retain a desirable amount of detail and a usable frame rate, the decision was made to present each building individually during the user test instead of the entire building block at the same time.

Layar 3D Model Converter

In order to be able to display 3D models, Layar needs its own .l3d format as input. The Layar 3D Model Converter tool can transform most popular formats (.obj/.mtl) into the required Layar format. The most important transformation this tool applies is that Layar requires all polygons to be triangles. By transforming the model, rectangles are converted into triangles, effectively doubling the amount of polygons in the model.

So instead of using extrusion to create windows or other details, it is suggested to use texture images instead. However, the converter does not accept any photograph as a texture. It only accepts texture files that can be tiled, which means they need to have dimensions to the power of 2 (16x16, 32x32, 256x128 etc.). So when using photographic material as textures for model details in order to decrease the model size, the time required to pre-process these texture images in Photoshop should not be underestimated. This resulted in the choice for creating the buildings fully in 3D, using Sketchup texture pre-sets which can be modified in Photoshop.

The converter also supports a model placement tool with an integrated Google maps feature (Figure 22). But because the placement of the historical buildings is based on the historical cadastre map, not the current parcel partition, this feature was not used.

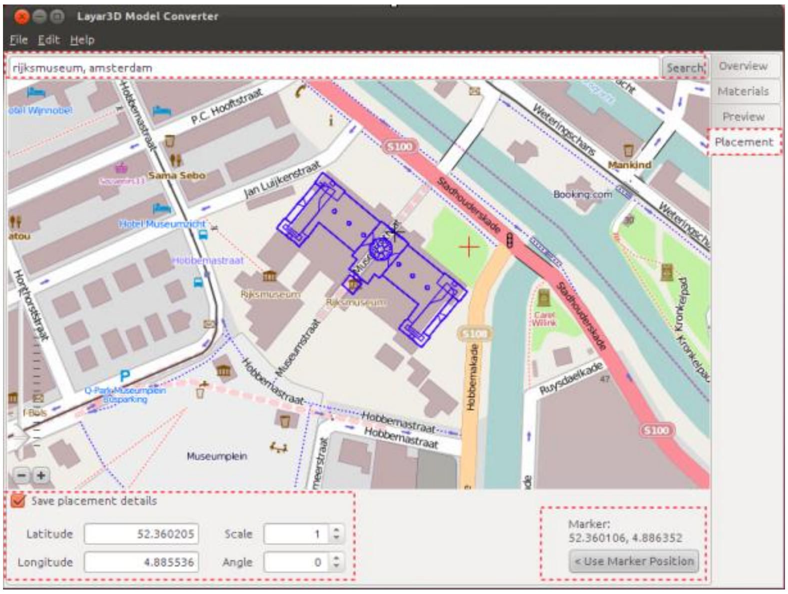


FIGURE 22 LAYAR MODEL PLACEMENT TOOL.

Not all models were converted correctly on the first try. Some of the faces changed texture, or were converted to triangles incorrectly, obscuring for example transparent window polygons. This resulted in some trial and error making numerous adjustments in Sketchup and converting the models multiple times in order to determine the conflicting geometry or textures. One of the buildings (Figure 23, Figure 24) generated so many errors, that after some corrections the decision was made to omit this model from the application and survey content. This did not have a big impact on the survey, because this building is situated on the far right side of the building block opposite another building block, and therefor difficult to view up close in the study area.

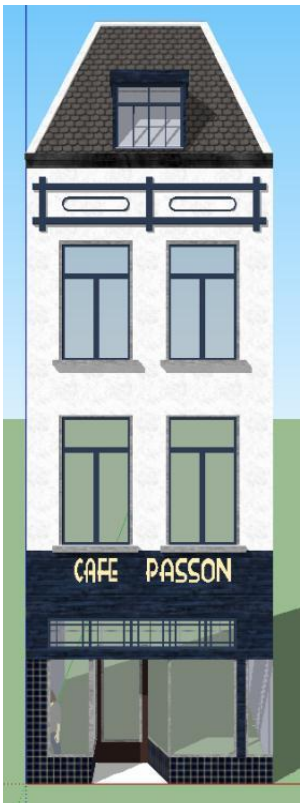


FIGURE 24 SKETCHUP PREVIEW

FIGURE 23 LAYAR MODEL CONVERTER PREVIEW

4.3 Implementation in Layar

Content for the Layar application is simply called a “layer”. The settings for the layer can be customized on the Layar website. Within this environment the data connections between the web service (PorPOIse API endpoint) and the Layar server can be established. The website also has a layer testing environment where the positions of the POI’s and settings can be tested, as well as verify the JSON response. When the Layar service and layer characteristics are defined, the next step is to position the points of interest.

4.3.1 Positioning the POIs

All data presented in Layar needs to have a location, be it GPS coordinates or visual, in order to become a so called Point of Interest (POI). Positioning the POI’s within Layar with the use of PorPOISe turned out to be quite user friendly. The PorPOIse dashboard function provides an intuitive point-and-click tool to place a marker on a map provided by Google Maps (Figure 25). Positioning the historic buildings was done by comparing their location in 1935 to the 2004 cadastre map, and comparing those coordinates with the position in the PorPOIse dashboard tool. Layar supports a “fixed location” function in the application, allowing you to view the Layar content within the Layar browser on a smartphone at any given location. This enables good control of the position of the objects relative to each other. Subsequently, the markers’ locations were verified on-site with the use of the smartphone to see if the GPS accuracy was sufficient for an acceptable placement of the building models (See Figure 26).

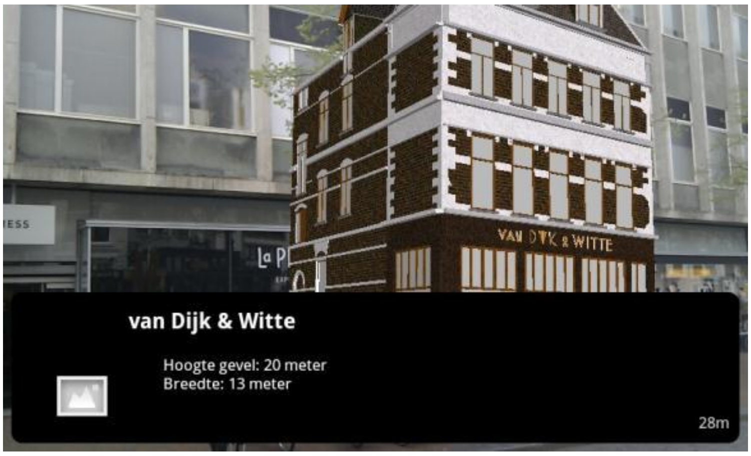


FIGURE 26 ON-SITE PROJECTION OF 3D MODEL "VAN DIJK EN WITTE" IN LAYAR CLIENT

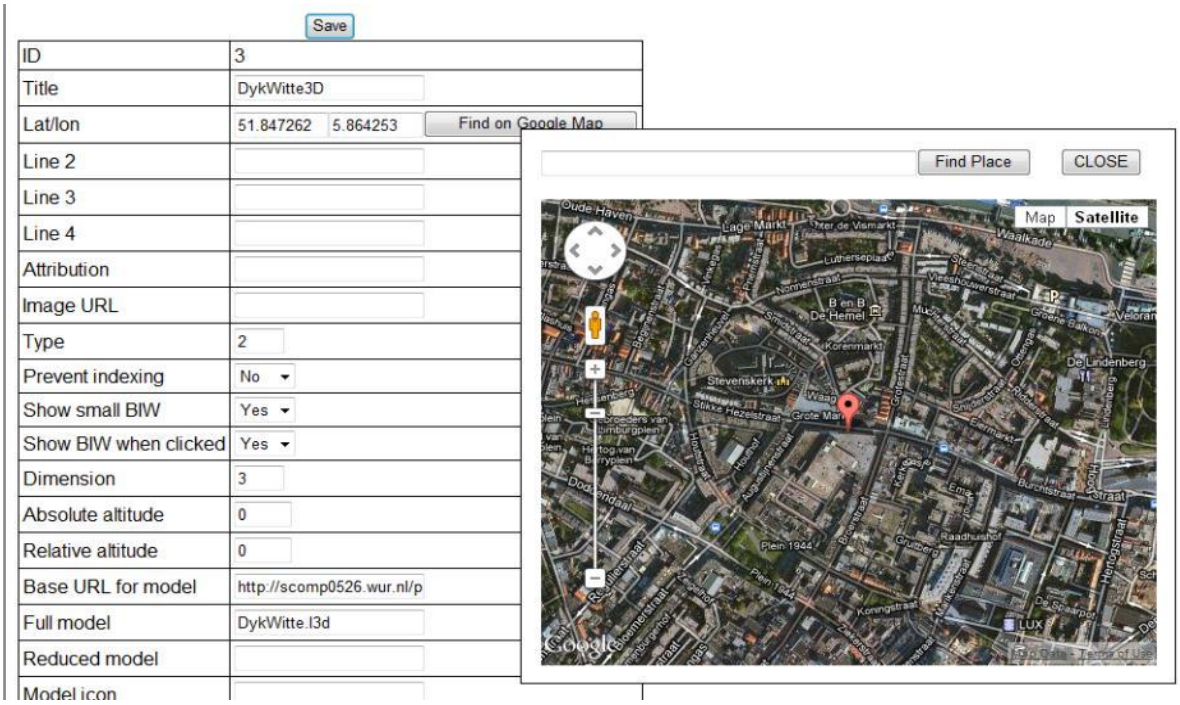


FIGURE 25 PORPOISE DASHBOARD GOOGLE MAPS IN TEGRATION

4.3.2 POI METADATA

Besides coordinates the Layar server also needs additional input to control how the POI and POI content is positioned within Layar. The most important parameters are listed in Table 4.

TABLE 4 IMPORTANT LAYAR PARAMETERS.

Parameter	Description
Dimension	2D or 3D
Alt	Altitude of the object relative to base level
Angle	Rotation of the object
BaseURL	Web location of the .l3d model/ image file
Size	Absolute height of the displayed object
Lat/Lon	Position of the object in coordinates
Type	Object category (used for filters)
Title	Title of the object/POI
Line1-4	Additional information to display

These parameters are defined for each POI individually in a .xml script (See Appendix IV Example Layar .xml script) which is fed into the PorPOIse server which converts it into a JSON response. The "Alt", "Angle" and "Size" parameters are crucial for positioning the models. Especially the angle is important because Layar positions the model facing North by default, which therefore needs to be corrected. Layar needs to be able to access the data freely, therefore because the .l3d format was not set as a mime-type on the WUR server it could not be loaded in the application. This was however quickly resolved by setting the correct mime-type.

Besides positioning the POI's, Layar also needs a trigger in order to determine which POI needs to be activated at which moment or location. The most basic trigger is the "range", which can be set for each POI. The range determines how close the user needs to be to a POI in order for Layar to load the desired data. However, because the POI's in the study area are situated close together, namely a street of adjacent buildings, this type of trigger was not very usable. Other options are the use of a filter, or the recently integrated Layar Vision function which uses a visual trigger. Because this function is relatively new, there were not a lot of tutorial/manuals available. It was therefore decided to use the filter options instead.

4.3.2 USING FILTERS

With the use of a filter, the user can make a selection of which POI's are to be displayed or activated in the Layar application. PorPOIse requires a custom POIconnector in order to enable filters such as a checkbox or radio box list. With the enabling of such a list, the application features a separate window where the user can select individual or groups of POI's. For instance, the first option in the prototype was defined as "1. Het Straatbeeld" (Appendix V Cognitive run through application) When selected, the application loads the black and white photographs of the entire wall of buildings, as well as the audio file containing the corresponding information.

4.3.3 AUDIO CONTENT

The audio content was recorded using a professional Shure PG 48 Vocal Microphone and mastered using iZotope Ozone audio mastering software, according to "radio broadcast" standards to ensure good sound quality and clarity. The good quality was necessary, because the audio is played on the street with a lot of ambient noise. The audio also needed to be compressed into 128kbps mp3 files in order to reduce the files' sizes. This is quite important because the Layar application has to load the audio files via internet connection along with the 3D models; large file sizes are therefore undesirable. This compression however leads to reduced audio quality, therefor how higher the source files' quality the better.

The "script" that was used for the audio content is the same as the description of the buildings in the leaflet. With the exception that the user is guided through the tour, by telling them which option in the Layar application should be selected. The introduction was provided in print, to be read beforehand, because this would be quite a long story to listen to as well as result in a too large file size.

The audio was added as a separate POI at the same location as the building model. The function for audio playback is called an "action" and can be triggered by location or manual activation. For each part of the tour, that is to say for each filter option containing a separate 3D model, an audio POI was added linked to the corresponding audio file.

The result is a "Layer" with audio content. In Appendix V Cognitive run through applicationa cognitive run through the application is illustrated using screenshots of the smartphone display.

Chapter 5 User survey results

This chapter describes the outcome of the questionnaire used during the user test. For each topic, first the most important quantitative correlations are presented, and after that the more qualitative results are discussed. This includes aspects such as the evaluation of the different visualization methods and the usability of the augmented reality format. In total, 16 participants filled in the questionnaire, of which 10 people used the AR application and 6 people used the folder. Most of the survey results are of the ordinal kind: an evaluation in numeric expression between 1 and 5. Other results that are quantifiable, such as the number of buildings the users placed in the correct order on the map, should also not be considered as interval or ratio. Because the outcome is related to the knowledge level of the participants, we cannot say that someone who places 4 buildings in the correct order has twice the knowledge of the building locations than a person who places 2 buildings in a correct way. These results are therefor also considered as ordinal, which makes the Spearman's Rho coefficient the most suitable method of statistical analysis. A correlation between variables is deemed significant, when the Spearman Sig. level is 0.05 or lower. However, due to the small amount of participants this significance level is highly susceptible to outliers and therefore not in all cases a reliable indicator. Hence, the statistical results of this analysis are quite unreliable, but the observed trends within the data might indicate that some of the hypotheses contain a nucleus of truth and therefor warrant further study.

5.1 Topographical knowledge

The first hypothesis concerns the spatial knowledge the users might attain by using the AR application: *people using the application will remember more spatial information*, such as the location of the buildings and the historical layout of the streets. The participants were asked to draw a map of the locations of the historical buildings, in order to see how well the spatial information is communicated by either the folder or the AR application.

Not every participant was able to draw specific buildings, or remembered the Scheidemakersgas in the middle of the building block. But if you look at the graphs of Appendix X Survey results Topography, the participants using AR scored better on placing the Augustijnenstraat further to the right hand side. However, the Scheidemakersgas was drawn relatively more times by people using the folder.

If we look at the means for each medium, people using the augmented reality application show a mean of 2.9500 while users with the leaflet score 1.9167 (Appendix XIII SPSS Results, Table 11). This would suggest that using the augmented reality application leads to a higher score of topographical knowledge. However, as can be seen in de correlation matrix in Appendix XIII SPSS Results, Table 10, there was no significant Spearman's Rho correlation between the medium and the total topography score, or any of the components from this part of the survey. The position of Wallet (et al. 2011), among others, that augmented reality enhances peoples' ability to create mental maps is therefore not statistically supported by the outcome of this survey.

5.2 Perception of the study area

The second hypothesis concerns the perception of the area, and how people experience the Grote Markt. The assumption is that *people using the application will experience a significant change in area perception towards historical location*. But it is also interesting to see if the perception of other "functions" also changes significantly.

When we look at the graphs of Appendix XI Area perception we can observe a change in perception between the two medium formats. People using the folder experience the area more as a shopping district, while people using AR consider it less as a place to go shopping. The same trend is visible for the idea of a connecting road. This is remarkable, because the area is accessible to city busses which drive by frequently. People walking around with an AR device might be more directly confronted with traffic than people standing still while reading the leaflet. This presumption is however not supported by the survey results.

If we look closer at the correlation matrix of Appendix XIII SPSS Results, we can observe one significant trend. People using the AR application have a more positive shift in perceiving the area as a historical location than someone using the leaflet (Figure 27). This might support the claim of AR contributing to an immersive experience and thus enabling people to better comprehend the experiential message the medium is trying to communicate. The presumption is that people experience the content as more real, creating a more tangible experience compared to a printed folder. These survey results support that claim: the Spearmans Rho coefficient is 0.570, and indicates a significant relation between augmented reality and area perception, because the Sig. level is 0.027.

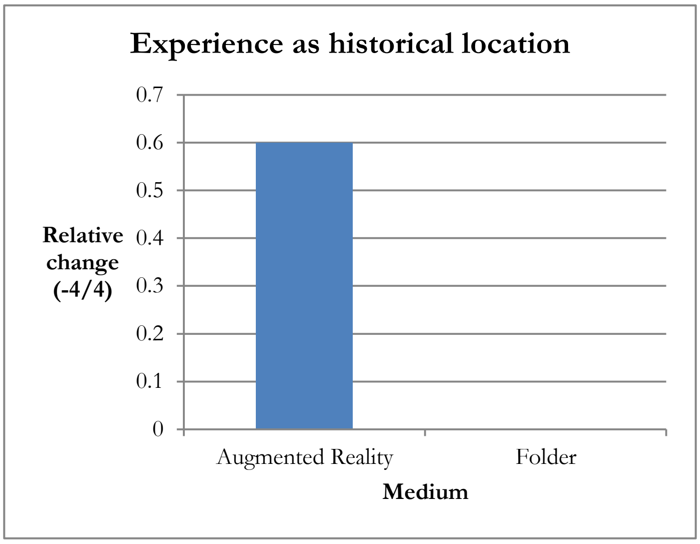


FIGURE 27 RELATIVE CHANGE IN AREA PERCEPTION FOR "HISTORICAL LOCATION" PER MEDIUM. N=16

The other functions of the area, shopping and connecting route, all seem to decrease more when the augmented reality application is used, but these trends are not significantly correlated according to the Spearman's correlation matrix. The significance level is quite low though, 0.096 and 0.095 respectively, so perhaps when the amount of users is increased these relations prove to be more significant.

5.3 Architectural knowledge

Concerning the communication of architectural knowledge people using the AR device scored less on all components compared to the folder guided participants. If we compare the correlation as well as the significance level of the total score and the corrected total score, an important change is observed. The *total score* shows a correlation of -0.449 with a Sig. of 0.081, while the *corrected score* shows a correlation of -0.603 with a Sig. of 0.013 (Table 6, Appendix XIII SPSS Results). So by correcting the bias of the baseline knowledge, both the correlation and the significance levels increase.

Because of the trends observed for all components, and the significant correlation attained by correcting the total knowledge score, we can say that the assumption that people using the folder can recollect more factual information is supported by the survey results. In other words, for communicating detailed information the use of a printed folder can be preferred.

However, a number of participants indicated that they were often distracted while using the application. Some said to be captivated by the visual models, and positioning these models on the camera view, to such an extent that they forgot to listen to the information provided via audio. If we therefore compare the knowledge score of AR users with their previous experience with smartphones, augmented reality or audio tours, one might expect to find a significant relation. There is some indication that users with a lot of experience with smartphones score higher when it comes to recollecting detailed knowledge (Appendix XIII SPSS Results, Table

13), however the significance level is above the desired 0.05. One participant remarked that he/she was so captivated and interested by the images and the actual buildings that the audio content was largely ignored. Another also remarked that handling the device and stabling the image led to too much distraction, preventing the participant from listening attentively. These factors might therefor explain the lower knowledge score of AR users.

5.4 Evaluation of visualization styles

Amongst both user groups the black and white photos, as well as the close-ups, were evaluated quite similar. The group using the AR application did however rate the 3D visualizations slightly better (Figure 28) (Appendix XII Evaluation of visualization styles). If we look at the Spearman's Rho correlation coefficient of 0.487 this relation is almost statistically significant with a Sig. level of 0.056 (Appendix XIII SPSS Results, Table 15 SPSS Results Spearman's rho correlation between medium and visualisation styles).

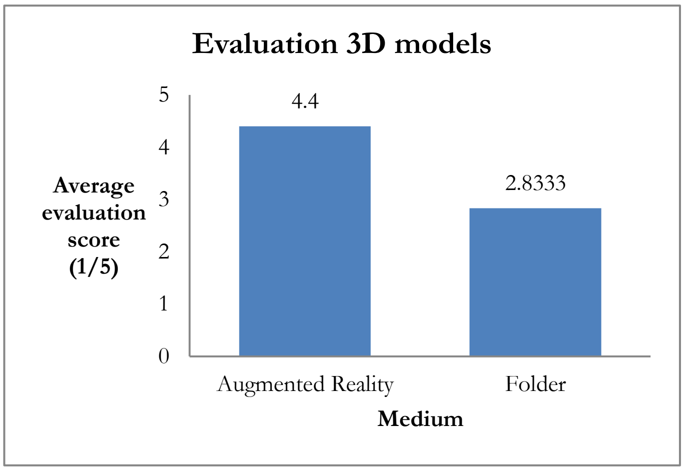


FIGURE 28 EVALUATION OF 3D MODELS PER MEDIUM. N=16

The questionnaire on visualization styles mainly resulted in a lot of quantitative written feedback. For instance, some of the people from *the user group using the folder* mentioned that the black and white photographs offered a good impression of the historical situation, and leave behind the most "authentic" impression of the buildings. The 3D models were sometimes difficult to understand because they were presented as a static image. However some claimed it did have an added value, because it showed a more spatial perspective and insight compared to the photographs, and also the use of colour was cited as a positive addition. The black and white close-ups of the architectural details were mostly rated as useful, but not everyone admitted to studying them intensively. Some evaluated the close-ups as a clear representation of the details described, though others found it reasonable, or even not clear enough, when sharpness or resolution was concerned.

People using the AR application found that the black and white photographs gave a good impression of the past, and that it places the historical images in context in a confronting and comprehensible way and communicates the architectural styles quite well. The photographs provided a clear image of the historic situation, especially when it comes to atmosphere; some therefore said it creates a nostalgic experience. Most users cited the images as the most natural looking, or realistic and truthful representation while retaining a historical feeling. It can provide a lot of info, yet without becoming too distracting.

Some found that the 3D models provide a more realistic experience, because it generates an image of the buildings from multiple perspectives and is therefore considered very useful for viewing the side of a building such as the van Dijk & Witte on the corner of the Scheidemakersgas. It provides a clear image of the buildings but is lacking in the aforementioned atmosphere. It does however enable people to better see the spatial relations between the models and reality. The colour and perspective offer more information, but are experienced as less historically real. Someone therefore said it can be useful as a supplement, when more information needs to be communicated in addition to the B&W photographs.

The close-ups were perceived as a nice and interesting addition because they are a better representation of the architectural details, and also because the 3D models of the concerning buildings remain visible in the same view. It enables a very clear view without having to walk really close to the model objects. However, some users said that the close-ups were not projected on a visible or useful location; one user didn't even notice the close-ups or mistook them for bugs in the application. The visibility of the close-ups turned out to depend strongly on the weather conditions. Especially the amount of sunlight on the screen can cause the B&W close-ups to become inconspicuous.

Although not statistically proven, the additional feedback by the users does support the hypotheses that the AR users evaluate the 3D models more positive than the users of the paper folder.

5.5 Augmented reality usability

As a whole, the application was evaluated quite positively (see Figure 29). Respondents remarked that the interactive qualities of the medium were enjoyable, and the technique itself was more than once perceived as remarkable. But the fact that people find the medium attractive, does not necessarily mean it is effectively communicating the desired information. For instance, users remarked that excessive sunlight on the screen made the content badly visible. Even though the coloured 3D models were often still visible, the black and white close-ups were difficult to distinguish from the background.

Navigating towards the filter window in Layar did not turned out to be very user-friendly because quite a number of actions need to be performed in order to get there. This does not provide a smooth tour experience, but when most of the users performed the set of actions a couple of times it no was no longer conceived as an obstacle.

Pointing the smartphone and listening to the audio content at the same time was sometimes experienced as tiresome, both mentally as well as physically. Stabilizing the image to keep the models from jumping around can be too distracting, causing people to forget to listen to the audio. The sunlight turned out to be a big problem as expected, making it hard to see what's happening on the screen. Also, the amount of information presented in multiple forms, audio, visual and navigating in the real world, was sometimes experienced as a bit overwhelming. More freedom of movement was sometimes desired, for instance being able to move further away from the objects allowing the models to be viewed in its entirety on the small screen. This can attributed to the study area, which is confined to some degree, or the size and resolution of the screen.

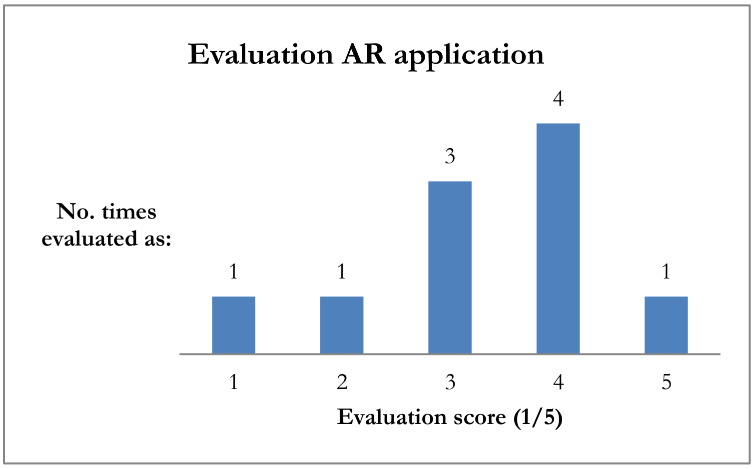


FIGURE 29 USER EVALUATION OF THE AUGMENTED REALITY APPLICATION. N=10

The most occurring problems are summarized in Figure 30. The biggest were, as mentioned before, the GPS accuracy, but also the loading times and screen visibility. As a whole, the formats' usability is evaluated as acceptable, but still limited by the technical specifications of the mobile device used.

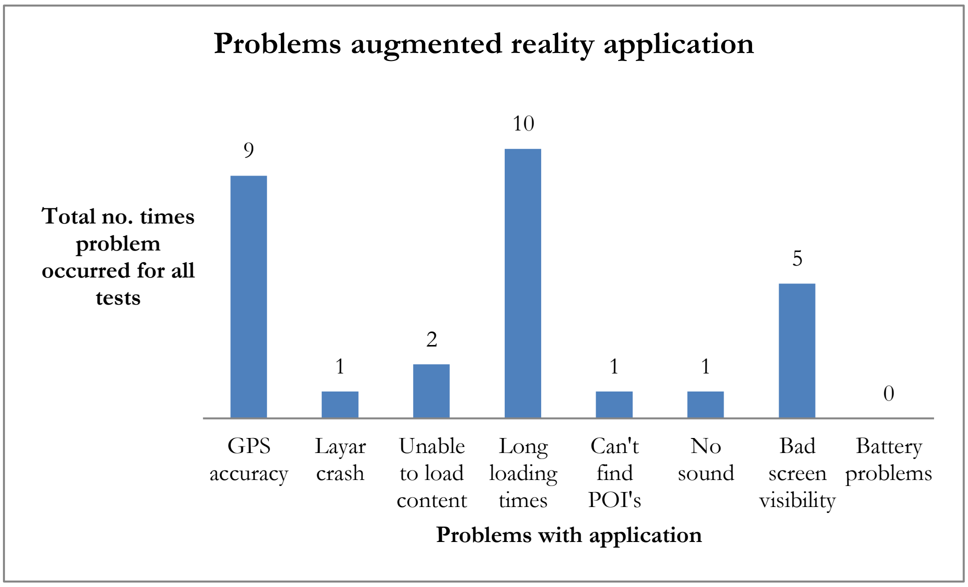


FIGURE 30 NUMBER OF TIMES PROBLEMS WITH THE AUGMENTED REALITY APPLICATION OCCURED. N=10

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The goal of this study was to research how the awareness of cultural heritage can be improved by visualizing digital cultural heritage through mobile augmented reality techniques. In order to do this, a number of research components were defined.

What constitutes the awareness of cultural heritage?

Awareness is a very broad term, but in relation to cultural heritage can be defined both as “having the notion it (cultural heritage) exists”, as well as a process of remembering and a core element of identity formation of time and place. The concept of awareness therefor surpasses the level of individual objects, and also adheres to the context and surroundings of these objects. Hence, the perception of a certain location is just as important as the perception of a historical artefact or building. But it’s not just about physical encounters, it’s also about communicating and recollecting information. Different types of visitors, or heritage users, experience different types of awareness. The most important components for raising awareness are therefore communicating information towards a specific user group, of which not only the object, but also the object’s surroundings in a certain period of time are of importance. The components that were identified for this study; information about an object as well as the object’s surroundings in place and time, are *the architectural styles of the buildings* (object) on “*de Grote Markt*” (surroundings) between the year *1935 and now* (time).

How can cultural heritage be visualized digitally?

Within the heritage field digital reconstructions and applications are becoming more popular. An important debate within digital reconstructions is about the tension between historical accuracy, visual realism and attractiveness, each largely determined by the available source material. For the reconstruction of urban areas or individual buildings, a number of modelling techniques are suggested, such as 2D, 2.5D, 3D, manual modelling, procedural/automated modelling and tour-into-the-picture. The preferred technique depends on the scale of the environment, the amount of detail or realism that is desired, as well as the time that is available for creating the models. For this study, the manual approach is explored by creating schematic 3D models of the historical buildings of the case study area, as well as by using black and white photographs. The focus of these visualizations is on the architectural styles of the buildings, using colour and textures to depict building materials and (where possible) high-resolution photographs of important architectural details.

How can digital heritage models be communicated using mobile augmented reality?

Mobile augmented reality enables the overlay of spatially referenced digital models on the camera image of a handheld device such as a modern smartphone. This requires the user to be on-site, pointing the device towards the visual content. In addition to the visual models, text fields and audio files can also be used. For this study, a combination of the visual overlay of digital models and a guided audio-tour is used.

The added value of augmented reality is determined by creating two user groups: one using the AR application and the other using a printed folder containing the same visual and factual information. The survey outcomes are compared to see what kind of information, and to what degree, is communicated best with the use of augmented reality. A distinction is hereby made between topographical knowledge, factual knowledge and the perception of the area. In addition the users are asked to evaluate the different types of visualization styles to see if certain visualization styles are more suited for augmented reality.

When it comes to *topographical knowledge*, the survey outcome does not show a statistically significant difference in spatial knowledge between the two communication formats, but the AR users do have a higher average score than people using the folder. *Factual knowledge* proved to be better communicated with a folder: most AR users claimed to be preoccupied with handling the device and visual content that they were too distracted to listen to the presented information. However, the users' *perception of the area* changed more significantly towards "historical location" with the use of the AR application. In terms of communicating the idea of a historically significant area the format of augmented reality might therefor be useful.

The evaluation of the *visualization styles* were not significantly correlated with the different communication formats. The AR users did prefer the 3D models more because of a higher level of interaction when it comes to scale and perspective; characteristics that are lost on a static paper presentation. In both formats, the black and white photographs were said to offer a more authentic impression, supported by the close-ups highlighting important details.

How can an improvement of heritage awareness be measured?

In order to determine whether the level of awareness is changed, this abstract concept needs to become measureable. The change in awareness can be measured by conducting a user survey, one before and one after communicating the desired information. The first survey establishes a knowledge baseline on the object, as well as the perception of the environment as a whole. If the second survey is compared to the first survey, a change in knowledge as well as perception of the area can be observed, which in turn could indicate a change in awareness.

Concluding

For raising heritage awareness, this study indicates that the presentation of digital heritage models through mobile augmented reality can be a good format to influence people's perception of their environment. However, the medium's novelty and technical limitations on smartphones seem to influence the communication of more factual knowledge, through text or audio, in a negative way. Technical limitations however are temporary, with smartphones becoming increasingly more powerful. In addition, when the concept of mobile augmented reality is no longer new, the initial "wow-factor" is eliminated, and the communication of factual knowledge might also improve.

The approach in its current form is therefore not completely suited for attaining increased heritage awareness. But in a situation where the usage of augmented reality is more common, on more powerful hardware, the communication of both factual and spatial knowledge could improve heritage awareness significantly.

6.2 Discussion & Critical Reflection

While conducting this thesis research a number of considerations and decisions were made that influenced the methodology and research outcome and might therefore warrant some further explanation.

The number of participants for each medium is unevenly distributed. There were 10 persons who used the augmented reality application and 6 users who used the folder. This second number is limited, because of the publication of an article in "de Gelderlander" about this thesis research. However appreciated, this publication was a timed a bit unfortunately. The article divulged information which was part of the application's content, such as pictures of the 3D models and architectural information. The participants who were willing to partake in the survey claimed to have read the article with great interest. Unfortunately this made them no longer suitable for being part of the survey, for they had already just seen the information that needed to be communicated with the folder. When additional respondents, who did not yet read the article, could not be found on such a short notice the decision was made to keep the number of respondents for the folder at 6.

In hindsight, some of the survey questions could also have been formulated more clearly. For instance, one of the questions was "How often do you visit the Grote Markt", of which people could choose between 5 options: "never, rarely, occasionally, often, a lot". However, these answers can be highly subjective. For someone who is a Nijmegen resident visiting the area 2 times a week may seem "occasionally", while for someone from outside the city this could be experienced as "a lot". The outcome of this question is therefore not very reliable.

The quantitative statistical analysis of the survey results was, due to low the number and uneven distribution of respondents, not very representative for this research outcome. Even though some correlations were found, the most tangible results were derived from the qualitative survey questions dealing with the evaluation of visualization types and usability of the AR format. With more time and a more detailed survey on a larger scale this research might yield more reliable results because this study's outcome does suggest that a number of the hypothesis posed in chapter 3 contain a notion of truth.

Within the AR application black & white close ups of architectural details are displayed alongside a 3D model. This means there are two different scale levels presented to the user at the same time. The effect of multi-scale visualization on the user's experience and perception of space was not taken into account. Spatial entities at different scales involve different cognitive processes (Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006), which suggests different types of knowledge transfer for different scale levels. For future research, this difference in perception warrants more careful consideration.

The tracking accuracy of GPS within urban areas is quite low. Even though the case study area consists of an open square, the projection of the Layar content turned out to be troublesome as soon as the user was positioned too close to the surrounding buildings. When it comes to visual environment tracking, using a feature database requires a lot of processing power of the AR device. Recent applications (Jung, Ha, Lee, Rojas, & Yang, 2012) have reduced technical specifications for scalable and even natural feature-based tracking substantially. Integrating these techniques into mobile augmented reality applications is therefore only a matter of time. Especially in the case of urban areas, with a lot of tracking objects within the camera view, the projection accuracy of 3d models such as used for Nijmegen will be much higher. However, taking into account the current technical possibilities of mobile augmented reality on smartphones, the projection of 3d building models in urban areas is not recommended.

6.3 Recommendations

Based on this study's outcome, suggestions for further study can be made for three distinct components: the AR device used, the quality of the digital models or content and the previous augmented reality experience of the user group.

The device used in this study was hand-held operated with limited technical specifications. A hands-free device, such as the Google "project glass" might prove to be more intuitive in use and therefore less distracting. Because the augmented reality audio tour requires several activities at the same time, such as handling the device, listening to the audio and looking at the visual content, users find it hard to concentrate on the information that is presented. This suggests that the ease of use should be as high as possible, allowing the user to focus more on the application's content.

The quality of digital heritage models depends on two main factors: the desired quality or sense of realism at one hand, and the technical specifications of the device and mobile network that is available on the other.

Displaying the models used in this study required a lot of computation power of the smartphone, allowing for only one model to be displayed at the same time. By using less detailed models, more content could be visualized at the same time. But then again, this is a consideration that has to be made for each project individually.

Though not statistically proven, a large number of the users found that handling the device distracted them from listening to the audio content. The convenience with which the user can operate the device is important for the effective communication of knowledge, in any case for the use of audio. For further research the recommendation is therefor to take the user group's previous experience with augmented reality into consideration, for this could have significant influence on the communication of heritage awareness.

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APPENDIX I HISTORICAL PARCEL MAP

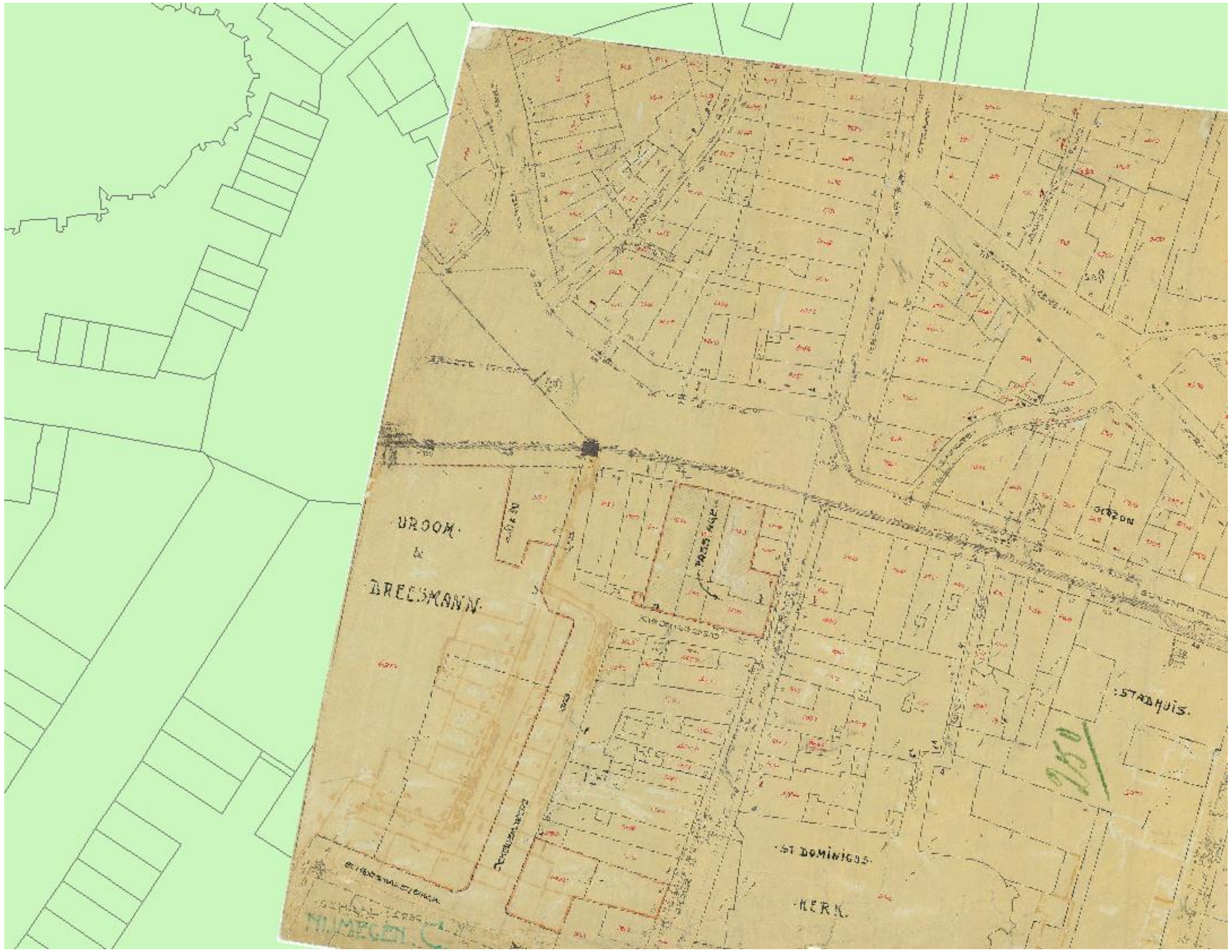

FIGURE 31 2004 PARCEL MAP OVERLAID PARTLY WITH HISTORICAL 1939 PARCEL MAP

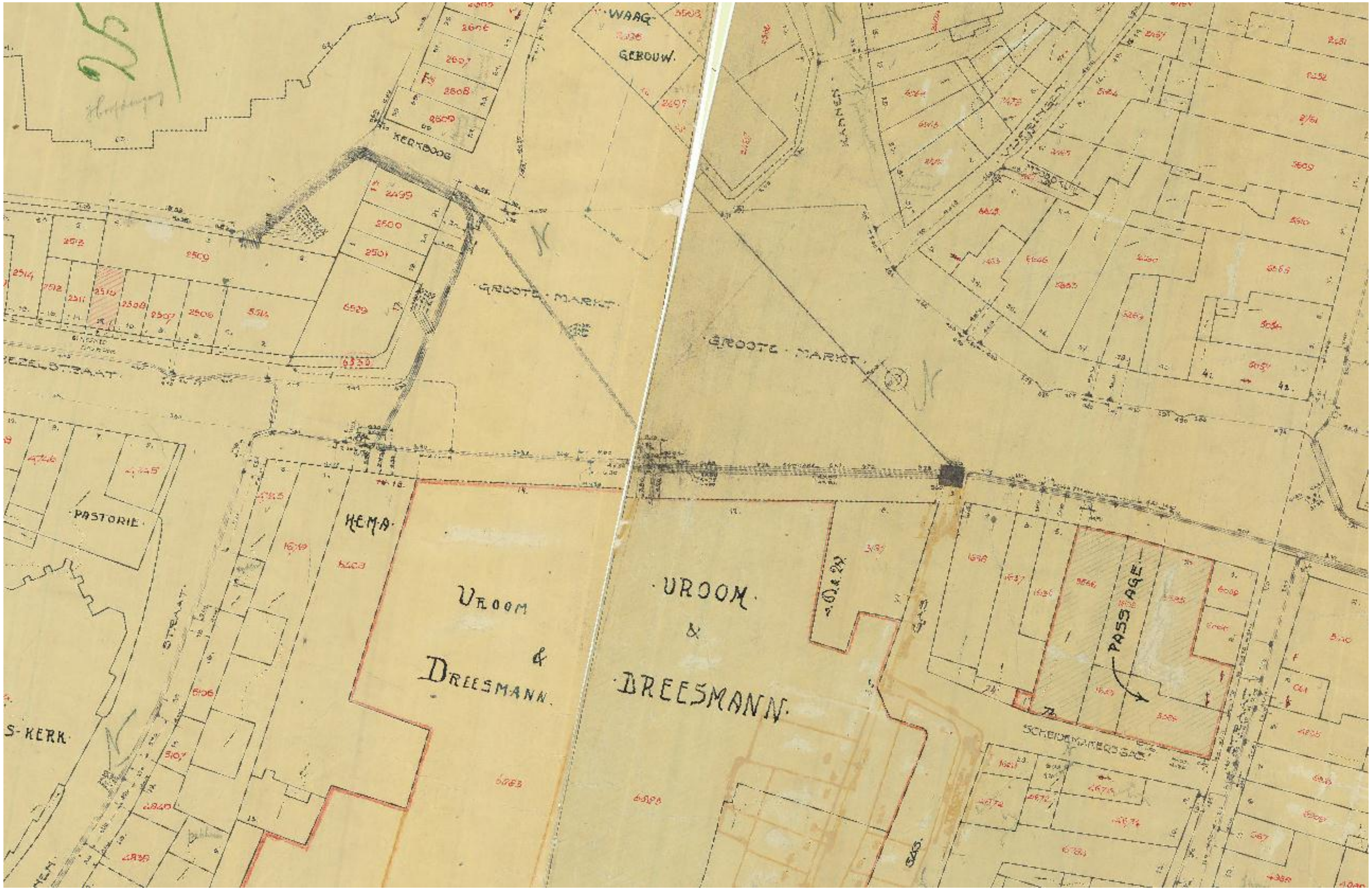

FIGURE 32 GEOREFERENCED 1939 PARCEL MAP

APPENDIX II ARCHITECTURAL STORY (IN DUTCH)

U staat nu op de Grote Markt. Een historische locatie, aangezien Nijmegen al in de Romeinse tijd bekend stond als een handelsnederzetting. De romeinse naam voor de stad, Noviomagus, betekent dan ook letterlijk "Nieuwe Markt". In de loop der eeuwen heeft de Grote Markt haar centrale functie in stand weten te houden, zoals dat op dit moment nog goed te zien is.

De aanwezigheid van bekende monumenten zoals de Waag en het St. Stevens poortje benadrukken een rijke architectonische geschiedenis, en ook de gevels boven de velen cafés laten de verschillende bouwstijlen zien die van de grote markt het plein hebben gemaakt dat het nu is.

Wanneer we echter kijken naar de zuidwand van het plein, zien we de HEMA rechts, en de V&D links, de ruimte vullen tussen de Broerstraat en de Augustijnenstraat. De modernistische gebouwen uit de jaren '60 onderscheiden zich van de historische omgeving door hun monumentale postuur en afwijkend materiaalgebruik. Gebouwd in de hectiek van de wederopbouw, waarbij Nijmegen het doel had gesteld om het centrum zo snel mogelijk weer op te bouwen, werd minder aandacht besteed aan vorm, terwijl functie een grotere rol ging spelen.

Deze architectonische breuk met het verleden kent duidelijke oorzaken. Enerzijds had de ruimtelijke ontwikkeling van het stadscentrum een 30 tal jaren stilgelegen, waardoor de architectonische ontwikkelingen van de jaren '30 en '40 grotendeels aan het centrum voorbij zijn gegaan. Anderzijds was daar het bombardement in 1944, waarbij het grootste gedeelte van het hoger gelegen centrum verloren is gegaan. Dit resulteerde in omvangrijke braakliggend stukken terrein te midden van het historische centrum, grote open plekken die naar een overwegend modernistische stijl zijn volgebouwd.

U ziet nu zwart wit foto's van de gebouwen die rond het jaar 1935 op deze locatie stonden. De situatie zoals deze voor het bombardement was, laat in vergelijking met de huidige situatie een duidelijk verschil zien in het stratenpatroon. De zuidwand was in zijn geheel een stuk breder dan nu, dit komt doordat de Augustijnenstraat voor de wederopbouw verder naar het westen lag. Dit gaf het plein een veel geslotener karakter, in tegenstelling tot de brede Augustijnenstraat die nu direct op de Grote Markt uitkomt.

De gebouwen zoals deze rond 1935 de zuidwand bekleedden sloten grotendeels aan op architectuur kenmerkend voor de laat 19^{e} en vroeg 20^{e} eeuwse Nijmeegse staduitleg. Dit is grotendeels terug te voeren op de invloed van één van Nijmeegse meest beeldbepalende architecten; Oscar Leeuw. Deze architect heeft in de periode tussen 1900 en 1940 een groot aantal kenmerkende gebouwen in Nijmegen ontworpen. Veel van deze gebouwen zijn in de oorlog verloren gegaan, maar bekende voorbeelden van nog steeds bestaande gebouwen zijn onder andere het concertgebouw de Vereeniging en Museum Kam. Oscar Leeuw was in deze periode tevens de huisarchitect van Vroom en Dreesmann in het oosten van Nederland, vooroorlogse vestigingen van deze winkelketen in o.a. Den Bosch, Eindhoven en Tilburg zijn van zijn hand.

Zo ook het V&D gebouw in het vooroorlogse Nijmegen. Zoals te zien is zat de HEMA vrijwel op dezelfde locatie. Links hiervan stonden twee grote panden beide in het bezit van V&D. Het pand direct links naast de HEMA, gebouwd in 1908 in opdracht van warenhuis Bahlmann & Co, is 1 van de vele gebouwen ontworpen door Oscar Leeuw.

U ziet nu het gebouw van Bahlmann. In de gevel zijn veel kenmerken van de Art Nouveau, of Jugendstil, zoals deze bouwstijl in ook wel in Duitsland genoemd werd, terug te zien in de cirkelvormige ornamenten en aansluitende gebogen lijnen. Ook in de kopstukken van de zuilen zijn de glooiende, haast organische lijnen terug te zien, wat kenmerkend is deze bouwstijl.

Ook het gebouw hier links van, het oorspronkelijke V&D gebouw uit 1916 wordt gekenmerkt door invloeden uit de Jugendstil periode, zoals de gedecoreerde bogen bovenin de gevel van het gebouw. Ook het kubisme van de Art Deco stijl begint in deze tijd langzaam zichtbaar te worden, zoals hier in de vorm van de vensters te zien is.

Op het bovenste gedeelte van het vooroorlogse pand van de HEMA zijn ook kenmerken van de Jugendstil terug te vinden, zoals de ornamenten net onder de daklijst, mozaïek en glas in lood ramen

Het pand links naast de voormalige V&D, herenmodezaak "van Dijk en Witte", werd gebouwd in 1892, in neorenaissance, of Hollandse renaissance bouwstijl. Deze bouwstijl was in de omringende wijken van het centrum langs de singels veelgebruikt rond het jaar 1900. Bij deze stijl werd teruggegrepen op motieven uit de renaissancebouwkunst. Kenmerkend hiervoor zijn het gebruik van donkerrode baksteen en witte, horizontale lijnen in de gevel, ook wel "speklagen" genoemd. Deze zijn ook duidelijk te zien in de zijwand van het gebouw, in het steegje tussen de twee huizenblokken in; het Scheidemakersgas. Dit kunt u zien door links om het 3D model heen te lopen.

Aan de andere kant van het steegje stond het hoekpand van de gebr. Raemakers, tevens een modezaak. Dit pand is een goed voorbeeld van een oudere bouwstijl; het (neo)classicisme, een stroming populair tussen 1640-1700. Bij het neoclassicisme werd teruggegrepen op de bouwkunst van de oude Grieken en Romeinen, zoals te zien is aan de verticale lijnen in de gevel die de illusie van pilaren creëren, en de puntvormige topgevel versierd met Romaans aandoende ornamenten. De twee pandjes hiernaast uit dezelfde periode vallen ook onder deze bouwstijl.

De situatie zoals deze zojuist is geschetst is aangrijpend veranderd toen het Nijmeegse stadscentrum in februari 1944 door de geallieerden werd gebombardeerd. De huidige panden van de HEMA en de V&D zijn ten tijde van de wederopbouw voor de oude panden in de plaats gekomen.

Dit is het einde van de rondleiding. U wordt nu vriendelijk verzocht het 2^{e} gedeelte van de enquête in te vullen.

APPENDIX III INSTRUCTIONS FOR AR APPLICATION

Historische Rondleiding

Architectuur geschiedenis en topologie van de Grote Markt te Nijmegen

U staat nu op de Grote Markt. Een historische locatie, aangezien Nijmegen al in de Romeinse tijd bekend stond als een handelsnederzetting. De romeinse naam voor de stad, Noviomagus, betekent dan ook letterlijk "Nieuwe Markt". In de loop der eeuwen heeft de Grote Markt haar centrale functie in stand weten te houden, zoals dat op dit moment nog goed te zien is.

De aanwezigheid van bekende monumenten zoals de Waag en het St. Stevens poortje benadrukken een rijke architectonische geschiedenis, en ook de gevels boven de velen cafés laten de verschillende bouwstijlen zien die van de grote markt het plein hebben gemaakt dat het nu is.

Wanneer we echter kijken naar de zuidwand van het plein, zien we de HEMA rechts, en de V&D links, de ruimte vullen tussen de Broerstraat en de Augustijnenstraat. De modernistische gebouwen uit de jaren '60 onderscheiden zich van de historische omgeving door hun monumentale postuur en afwijkend materiaalgebruik. Gebouwd in de hectiek van de wederopbouw, waarbij Nijmegen het doel had gesteld om het centrum zo snel mogelijk weer op te bouwen, werd minder aandacht besteed aan vorm, terwijl functie een grotere rol ging spelen.

Deze architectonische breuk met het verleden kent duidelijke oorzaken. Enerzijds had de ruimtelijke ontwikkeling van het stadscentrum een 30 tal jaren stilgelegen, waardoor de architectonische ontwikkelingen van de jaren '30 en '40 grotendeels aan het centrum voorbij zijn gegaan. Anderzijds was daar het bombardement in 1944, waarbij het grootste gedeelte van het hoger gelegen centrum verloren is gegaan. Dit resulteerde in omvangrijke braakliggend stukken terrein te midden van het historische centrum, grote open plekken die naar een overwegend modernistische stijl zijn volgebouwd.

Gebruiksaanwijzing Smartphone

U kunt als volgt door de rondleiding manoeuvreren:

- Druk op "apply" (Scherm)
- Voor het volgende gedeelte van de rondleiding
  - Druk op "menu" (Telefoon)
  - Druk op "Settings" (Scherm)
  - Druk op het "drop-down" knopje naast "rondleiding" (Scherm)
  - Vink de gewenste optie aan (Scherm)
  - Druk op de knop "vorige" (Telefoon)
  - Druk op "Apply" (Scherm)

Wanneer de applicatie vastloopt, u geen geluid hoort, of wanneer u andere problemen ondervindt, wees dan niet bang om hulp te vragen!

APPENDIX IV EXAMPLE LAYAR .XML SCRIPT


```xml
<!-- Option 3: "V&D" // 3D model + BW zoom + audio // 4 POIs -->

<!-- Visual -->

<!-- 3D model -->
<poi><dimension>3</dimension><alt>0</alt><transform><rel/><angle>175</angle><scale>1</scale></transform>
<object><baseURL>http://scomp0526.wur.nl/projects/nijmegen_1935/</baseURL><full>VDtoHema2.l3d</full><reduced/><icon/>
<size>23</size></object><relativeAlt>0</relativeAlt><attribution/><distance/><id>5</id><imageURL/>
<lat>51.847316876259</lat><lon>5.8636777364388</lon><line2>Hoogte gevel: 17 meter</line2><line3>Breedte: 27 meter</line3><line4/>
<title>Bahlmann &amp; Co</title>
<type>2</type><doNotIndex>0</doNotIndex><inFocus/><showSmallBiw>1</showSmallBiw><showBiwOnClick>1</showBiwOnClick>
</poi>

<!-- BlackWhite closeups -->
<poi><dimension>2</dimension><alt>0</alt><transform><rel/><angle>175</angle><scale>1</scale></transform>
<object><baseURL>http://scomp0526.wur.nl/projects/nijmegen_1935/</baseURL><full>GevelBahlmann1.png</full><reduced/><icon/>
<size>5</size></object><relativeAlt>16</relativeAlt><attribution/><distance/><id>31</id><imageURL/>
<lat>51.847336759766</lat><lon>5.8633773290292</lon><line2/><line3/><line4/>
<title>Bahlmann detail 1</title>
<type>2</type><doNotIndex>0</doNotIndex><inFocus/><showSmallBiw>1</showSmallBiw><showBiwOnClick>1</showBiwOnClick></poi>

<poi><dimension>2</dimension><alt>0</alt><transform><rel/><angle>175</angle><scale>1</scale></transform>
<object><baseURL>http://scomp0526.wur.nl/projects/nijmegen_1935/</baseURL><full>GevelBahlmann2.png</full><reduced/><icon/>
<size>5</size></object><relativeAlt>21</relativeAlt><attribution/><distance/><id>32</id><imageURL/>
<lat>51.847336759766</lat><lon>5.8633773290292</lon><line2/><line3/><line4/>
<title>Bahlmann detail 2</title>
<type>2</type><doNotIndex>0</doNotIndex><inFocus/><showSmallBiw>1</showSmallBiw><showBiwOnClick>1</showBiwOnClick></poi>

<!-- Audio -->
<poi><dimension>2</dimension><alt>0</alt><transform><rel/><angle>0</angle><scale>1</scale></transform>
<object><baseURL/><full/><reduced/><icon/><size>0</size></object><relativeAlt>0</relativeAlt>
<action>
<autoTriggerRange>1000</autoTriggerRange><autoTriggerOnly>1</autoTriggerOnly>
<uri>audio://scomp0526.wur.nl/projects/nijmegen_1935/audio/3VD.mp3</uri>
<label>Audio VD</label><contentType/>
<method>GET</method><activityType>0</activityType><params/>
<closeBiw/><showActivity>1</showActivity><activityMessage/></action><attribution/>
<distance/><id>6</id><imageURL/><lat>51.847306934502</lat><lon>5.8635784947053</lon><line2/><line3/><line4/>
<title>Audio VD</title>
<type>3</type><doNotIndex>0</doNotIndex><inFocus/><showSmallBiw>1</showSmallBiw><showBiwOnClick>1</showBiwOnClick>
</poi>
```

Appendix V Cognitive run through application

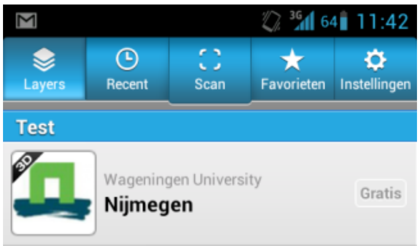

FIGURE 34 OPENING SCREEN APPLICATION

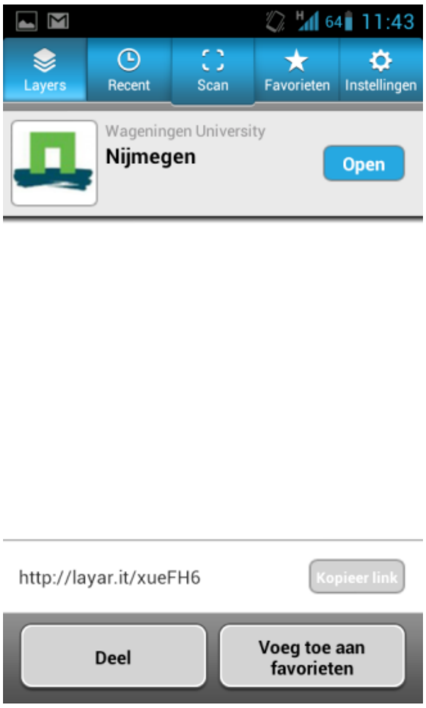

FIGURE 33 LAYER SELECTION

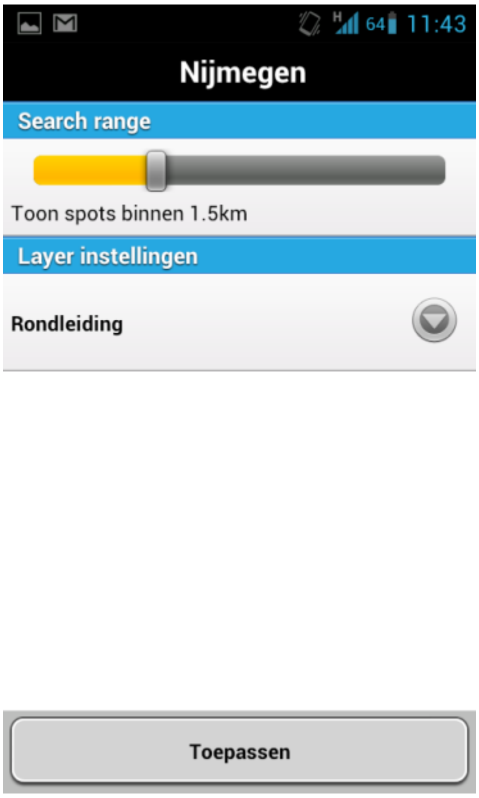

FIGURE 35 OPENING SCREEN LAYER

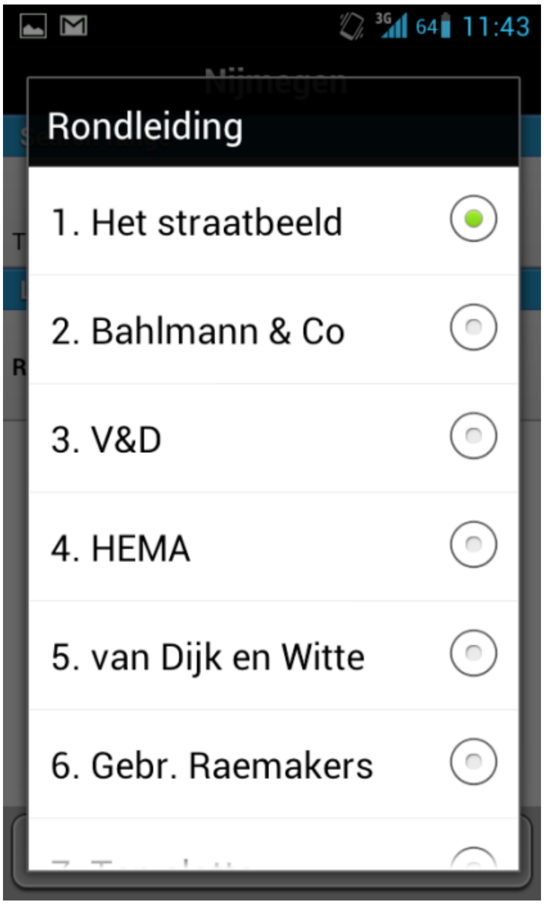

FIGURE 37 CONTENT SELECTION MENU

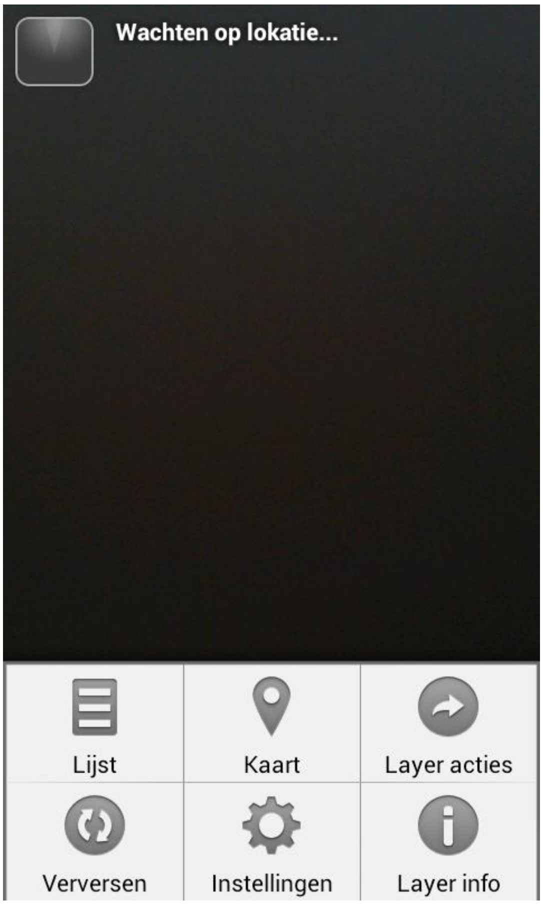

FIGURE 36 OPTIONS AFTER PRESSING "MENU"

The user is guided through the different options using audio.

When an option is selected, the content (both visual and audio POI's) load automatically.

When the factual audio content is finished, the user is asked to go to the next option in the menu.

APPENDIX VI ENQUÊTE VÓÓR GEBRUIK APPLICATIE

U heeft ingestemd om deel te nemen aan een gebruikers test van een “mobile augmented reality” applicatie over de architectuurgeschiedenis van de Grote Markt in Nijmegen. Hartelijk dank hiervoor. Augmented reality is een techniek die grafische informatie over de werkelijkheid heen kan leggen, in dit geval het camerabeeld van een smartphone. De applicatie maakt ook gebruik van een audio functie, waarbij u gedetailleerde informatie over uw omgeving te horen krijgt. Deze componenten vormen samen een interactieve audio-visuele rondleiding over de Grote Markt, waarbij u meer te weten komt over het architectonische verleden. U wordt naderhand gevraagd om een 2e enquête in te vullen over uw belevingservaring van de applicatie en de inhoud van de rondleiding.

Allereerst volgen een aantal vragen over uw ervaring met deze techniek, en uw huidige kennis m.b.t. historische stadsarchitectuur in Nijmegen.

Heeft u ervaring met het gebruik van…

	Heel weinig				Heel veel
Smartphones	O	O	O	O	O
Augmented reality	O	O	O	O	O
Audio-tours	O	O	O	O	O

(Paragraph 5.2 Perception of the study area)

Hoe vaak komt u in Nijmegen op de grote markt?

Nooit	af en toe	regelmatig	vaak	heel vaak
O	O	O	O	O

Hoe ziet u de Grote Markt? / Wat voor functie zou u aan de Grote Markt toekennen?

	Zeer weinig	Weinig	Neutraal	Veel	Zeer veel
Als winkelgebied	O	O	O	O	O
Als uitgaansgebied	O	O	O	O	O
Als doorgaande route	O	O	O	O	O
Als historische locatie	O	O	O	O	O
Anders, namelijk…	O	O	O	O	O

(Paragraph 5.3 Architectural knowledge)

In hoeverre bent u bekend met historische stadsarchitectuur in Nederland?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

In hoeverre bent u bekend met de architectuurgeschiedenis van de Grote markt?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

In hoeverre bent u bekend met beeldbepalende architecten van Nijmegen?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

Kunt u een aantal van die architecten noemen?

Kunt u een aantal architectonische stijlen noemen die kenmerkend zijn voor het historische straatbeeld van Nijmegen?

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APPENDIX VII ENQUÊTE NÁ GEBRUIK APPLICATIE

U heeft zojuist aan de hand van een interactieve applicatie op een smartphone een rondleiding gehad over de architectonische geschiedenis van de Grote Markt. Nu volgen een aantal vragen over uw beleving van de locatie en de inhoud van de rondleiding.

Beleving

(Paragraph 5.2 Perception of the study area)

Hoe ziet u de Grote Markt na de rondleiding? Wat voor functie zou u aan nu de Grote Markt toekennen?

	Zeer weinig	Weinig	Neutraal	Veel	Zeer veel
Als winkelgebied	O	O	O	O	O
Als uitgaansgebied	O	O	O	O	O
Als doorgaande route	O	O	O	O	O
Als historische locatie	O	O	O	O	O
Anders, namelijk…	O	O	O	O	O

Heeft u het gevoel dat het visuele aspect van de augmented reality applicatie, d.w.z. het zichtbaar maken van verdwenen gebouwen, bijdraagt aan uw culturele beleving van de locatie?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

(Paragraph 5.3 Architectural knowledge)

Heeft u het gevoel dat u na het gebruiken van de applicatie beter bekend bent met historische stadsarchitectuur in Nederland?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

Heeft u het gevoel dat u nu beter bekend met de architectuurgeschiedenis van de Grote Markt?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

(Paragraph 5.4 Evaluation of visualization styles)

In hoeverre vond u de visualisatie methoden van de gebouwen geschikt om meer te weten te komen over de architectuurgeschiedenis (bouwstijlen, kenmerken, details) van de Grote Markt?

	Zeer ongeschikt				Zeer geschikt
Zwart-wit foto's	O	O	O	O	O
3D modellen	O	O	O	O	O
Zwart-wit close-ups	O	O	O	O	O

Kunt u toelichten waarom u dit vindt?

Zwart-wit foto's

____

____

____

3D modellen

____

____

____

Zwart-wit close-ups

____

____

____

(Paragraph 5.3 Architectural knowledge)

Inhoud

Nu volgen een aantal vragen over de inhoud van de rondleiding, ik zou u graag willen vragen deze zo volledig mogelijk te beantwoorden.

Kunt u een voor Nijmegen beeldbepalende architect noemen?

Weet u nog welke gebouwen deze architect heeft ontworpen, in Nijmegen of elders?

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Kunt u een aantal architectonische stijlen noemen die kenmerkend zijn voor het historische straatbeeld van Nijmegen, weet u nog welke winkelketens een pand met dergelijke ontwerpen hadden?

Bouwstijl	**Winkelketen**	**Kenmerken**
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------

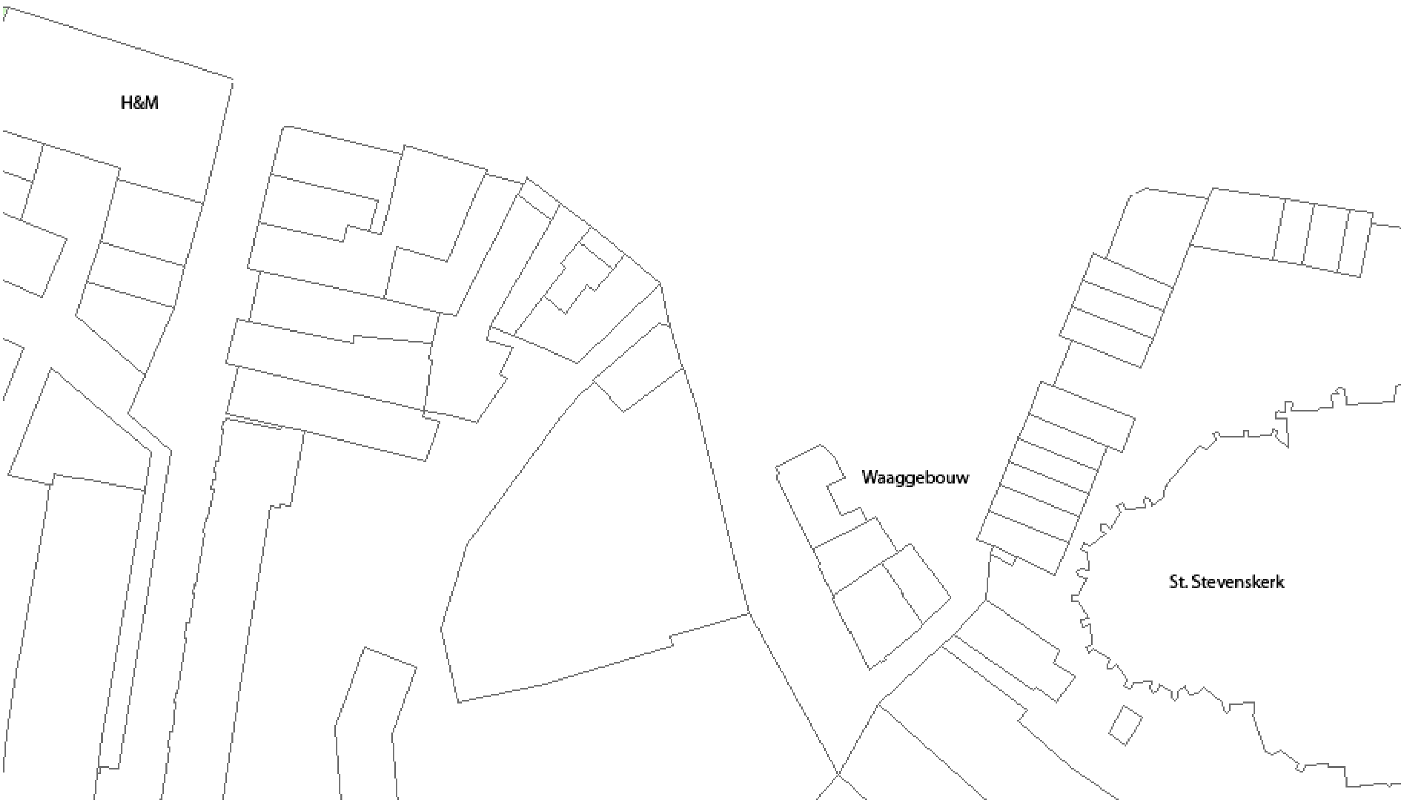
Kunt u de stijlen die u bij de voorgaande vraag heeft genoemd ordenen naar tijdsspanne?

Vroeg

Laat

(Paragraph 5.1 Topographical knowledge)

Kunt u de gebouwen en straten in plattegrondvorm intekenen op het kaartje hieronder?
Zou u hierbij per gebouw kunnen aangeven hoe hoog u de gevels van de gebouwen inschat?



Gebruiksgemak

(Paragraph 5.5 Augmented reality usability)

Ten slotte nog een aantal vragen over het gebruiksgemak van de applicatie…

Wat is over het geheel genomen uw ervaring met het gebruik van de smartphone applicatie?

Heel negatief		Neutraal		Heel Positief
O	O	O	O	O

Wat vond u van de audio component van de applicatie?

	Zeer negatief		Neutraal		Zeer positief
Verstaanbaarheid	O	O	O	O	O
Geluidskwaliteit	O	O	O	O	O
Anders, namelijk…	O	O	O	O	O

Zou u eventueel voorkeur hebben voor een geïllustreerde folder met informatie i.p.v. een audio tour i.c.m. de augmented reality applicatie?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

Bent u tijdens het gebruik van de applicatie tegen problemen aangelopen? Zo ja, welke? (Meerdere antwoorden mogelijk)

O Onnauwkeurigheid GPS / Objecten verspringen in het beeld
O De applicatie (Layar) liep vast
O De applicatie kon geen content (afbeeldingen, 3D modellen) inladen
O Het inladen van de content duurde erg lang
O De applicatie kon geen POI's (Points of Interest) vinden
O Het geluid viel uit
O Het scherm was slecht leesbaar (bijv. door weerspiegeling van de zon)
O De batterij van de telefoon was leeg
O Anders, namelijk:

Dit is het einde van de enquête, hartelijk dank voor uw medewerking.

APPENDIX VIII ENQUÊTE VÓÓR GEBRUIK FOLDER

U heeft ingestemd om deel te nemen aan een rondleiding over de architectuurgeschiedenis van de Grote Markt in Nijmegen. Hartelijk dank hiervoor. U zal hierbij gebruik maken van een informatieve folder met illustraties, waarbij u meer te weten komt over het architectonische verleden. U wordt naderhand gevraagd om een 2e enquête in te vullen over uw belevingservaring van de Grote Markt en de inhoud van de rondleiding. Allereerst volgen een aantal vragen over uw huidige kennis m.b.t. historische stadsarchitectuur in Nijmegen.

Hoe vaak komt u in Nijmegen op de grote markt?

Nooit	af en toe	regelmatig	vaak	heel vaak
O	O	O	O	O

Hoe ziet u de Grote Markt? / Wat voor functie zou u aan de Grote Markt toekennen?

	Zeer weinig	Weinig	Neutraal	Veel	Zeer veel
Als winkelgebied	O	O	O	O	O
Als uitgaansgebied	O	O	O	O	O
Als doorgaande route	O	O	O	O	O
Als historische locatie	O	O	O	O	O
Anders, namelijk…	O	O	O	O	O

In hoeverre bent u bekend met historische stadsarchitectuur in Nederland?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

In hoeverre bent u bekend met de architectuurgeschiedenis van de Grote markt?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

In hoeverre bent u bekend met beeldbepalende architecten van Nijmegen?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

Kunt u een aantal van die architecten noemen?

Kunt u een aantal architectonische stijlen noemen die kenmerkend zijn voor het historische straatbeeld van Nijmegen?

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APPENDIX IX ENQUÊTE NÁ GEBRUIK FOLDER

U heeft zojuist aan de hand van een folder een rondleiding gehad over de architectonische geschiedenis van de Grote Markt. Nu volgen een aantal vragen over uw beleving van de locatie en de inhoud van de rondleiding.

Beleving

Hoe ziet u de Grote Markt na de rondleiding? Wat voor functie zou u aan nu de Grote Markt toekennen?

	Zeer weinig	Weinig	Neutraal	Veel	Zeer veel
Als winkelgebied	O	O	O	O	O
Als uitgaansgebied	O	O	O	O	O
Als doorgaande route	O	O	O	O	O
Als historische locatie	O	O	O	O	O
Anders, namelijk…	O	O	O	O	O

Heeft u het gevoel dat u na het lezen van de folder beter bekend bent met historische stadsarchitectuur in Nederland?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

Heeft u het gevoel dat u na het lezen van de folder beter bekend met de architectuurgeschiedenis van de Grote Markt?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

Heeft u het gevoel dat het visuele aspect van de folder applicatie, d.w.z. de illustraties van verdwenen gebouwen, bijdraagt aan uw culturele beleving van de locatie?

Heel weinig		Neutraal		Heel veel
O	O	O	O	O

In hoeverre vond u de illustraties van de gebouwen geschikt om meer te weten te komen over de architectuurgeschiedenis (bouwstijlen, kenmerken, details) van de Grote Markt?

	Zeer ongeschikt				Zeer geschikt
Zwart-wit foto's	O	O	O	O	O
3D modellen	O	O	O	O	O
Zwart-wit close-ups	O	O	O	O	O

Kunt u toelichten waarom u dit vindt?

Zwart-wit foto's
____

____

____

3D modellen
____

____

____

Zwart-wit close-ups
____

____

____

Inhoud

Nu volgen een aantal vragen over de inhoud van de rondleiding, ik zou u graag willen vragen deze zo volledig mogelijk te beantwoorden.

Kunt u een voor Nijmegen beeldbepalende architect noemen?

Weet u nog welke gebouwen deze architect heeft ontworpen, in Nijmegen of elders?

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Kunt u een aantal architectonische stijlen noemen die kenmerkend zijn voor het historische straatbeeld van Nijmegen, weet u nog welke winkelketens een pand met dergelijke ontwerpen hadden?

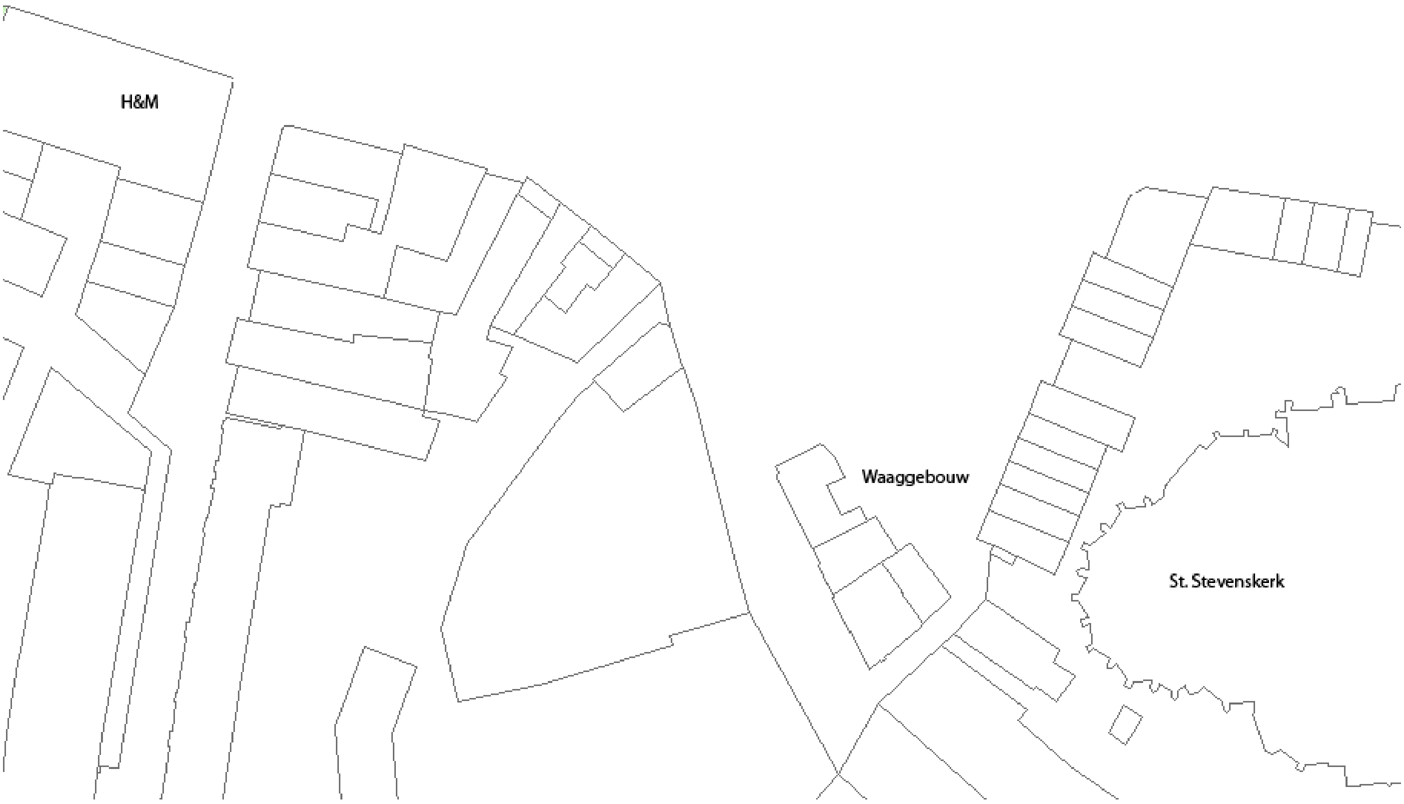
Bouwstijl	**Winkelketen**	**Kenmerken**
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------
------------------------------------	---------------------------------	--------------------------------

Kunt u de stijlen die u bij de voorgaande vraag heeft genoemd ordenen naar tijdsspanne?

Vroeg

Laat

Kunt u de gebouwen en straten in plattegrondvorm intekenen op het kaartje hieronder?
Zou u hierbij per gebouw kunnen aangeven hoe hoog u de gevels van de gebouwen inschat?



Dit is het einde van de enquête, hartelijk dank voor uw medewerking.

APPENDIX X SURVEY RESULTS TOPOGRAPHY

TABLE 5 TOPOGRAPHICAL KNOWLEDGE CRITERIA AND SCORE.

Criteria	**Score**
Did the user draw the "Scheidemakersgas"?	
Yes	1
No	0
Did the user place the Augustijnestraat further to the right?	
Yes	1
No	0
Number of buildings placed in the correct order left-right.	
1-2 buildings	1
3-4 buildings	2
Grid score: The absolute location of the buildings.	
Within buffer of 0 – 1 grid cells	1
Within buffer of 2 – 3 grid cells	0.5
Outside buffer of 4 grid cells	0
Total Topography Score	**Sum**

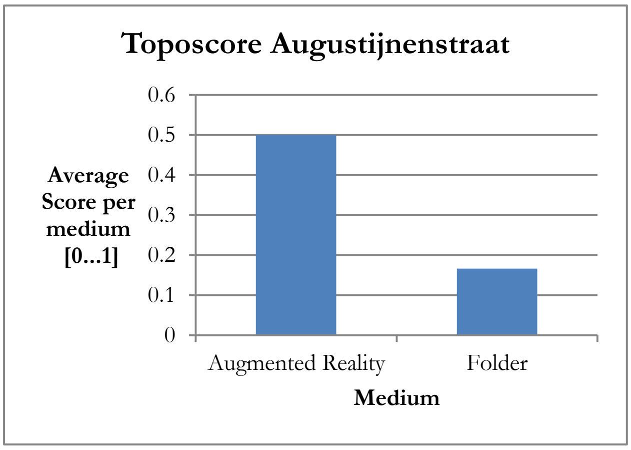


FIGURE 42 DIFFERENCE IN SCORE FOR DRAWING THE "AUGUSTIJNENSTRAAT". AR: N=10 | FOLDER: N=6.

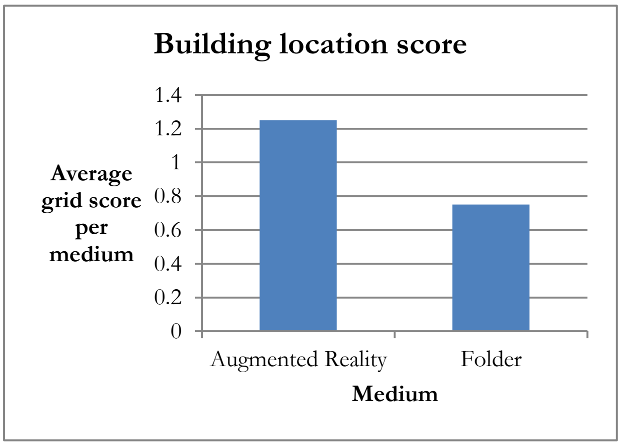


FIGURE 40 AVERAGE SCORE BUILDINGS PLACED AT THE RIGHT LOCATION. AR: N=10 | FOLDER: N=6.

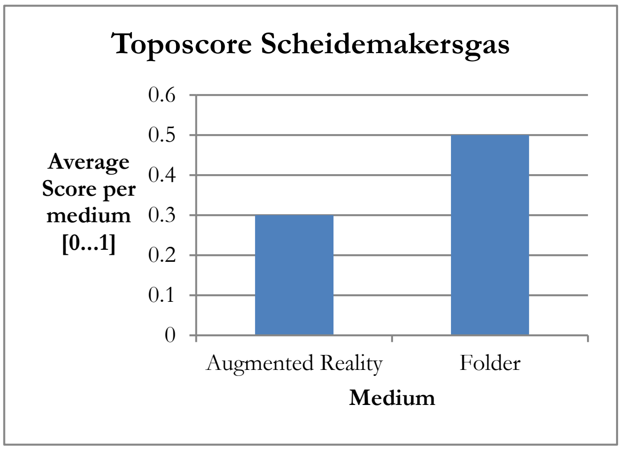


FIGURE 38 DIFFERENCE IN SCORE FOR DRAWING THE "SCHEIDEMAKERSGAS". AR: N=10 | FOLDER: N=6.

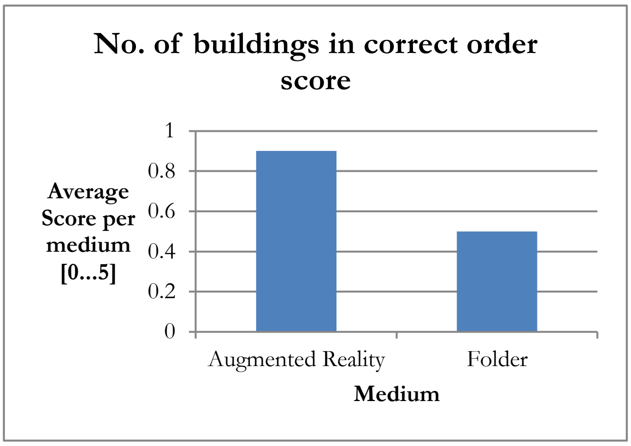


FIGURE 39 AVERAGE SCORE NO. OF BUILDINGS PLACED IN THE CORRECT ORDER. AR: N=10 | FOLDER: N=6.

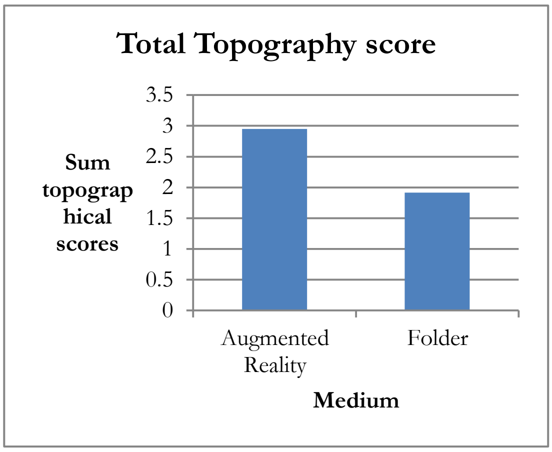


FIGURE 41 TOTAL SCORE TOPOGRAPHICAL LOCATION. AR: N=10 | FOLDER: N=6.

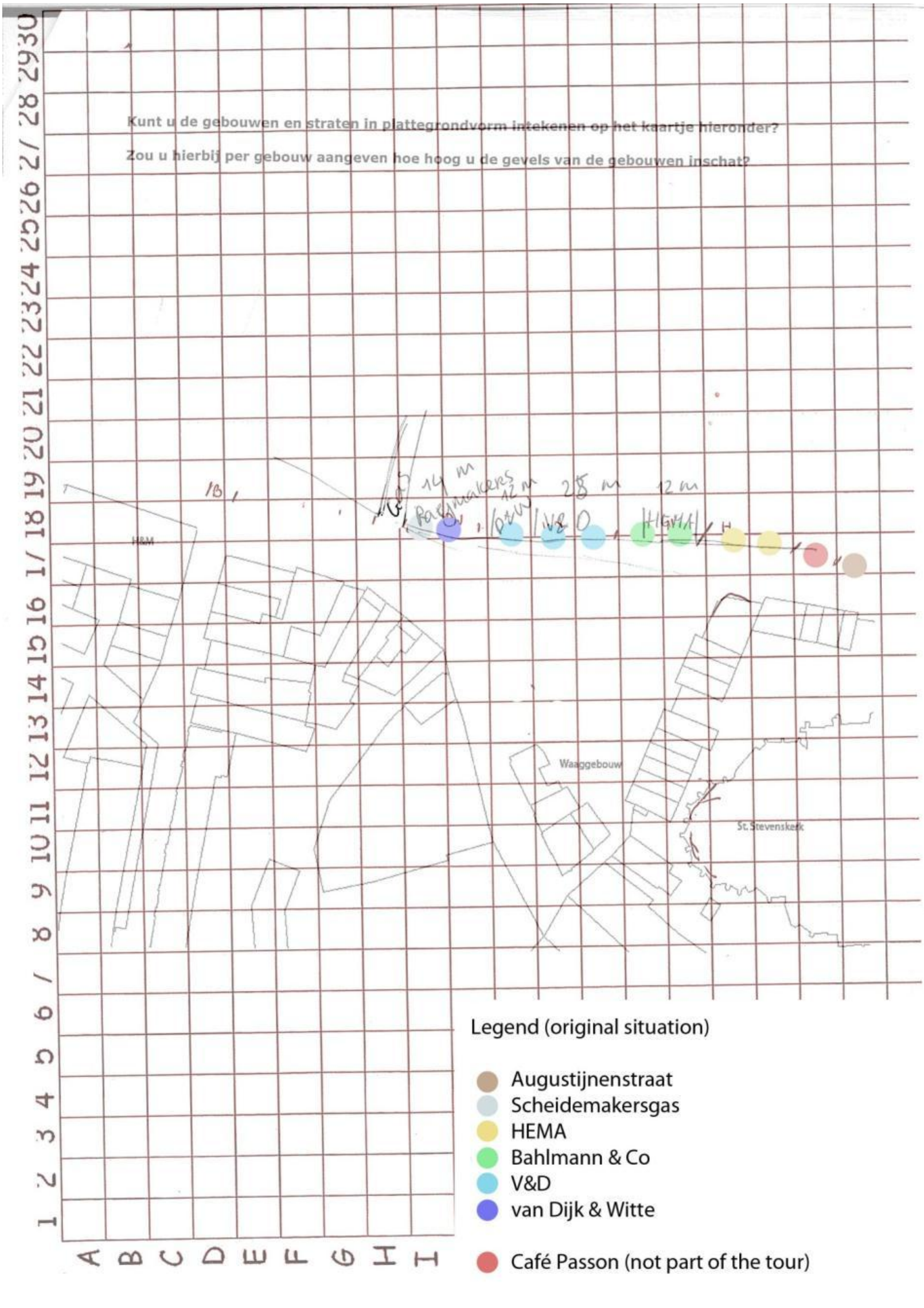


FIGURE 43 MENTAL MAP WITH GRID OVERLAY SHOWING A RELATIVELY GOOD RESULT

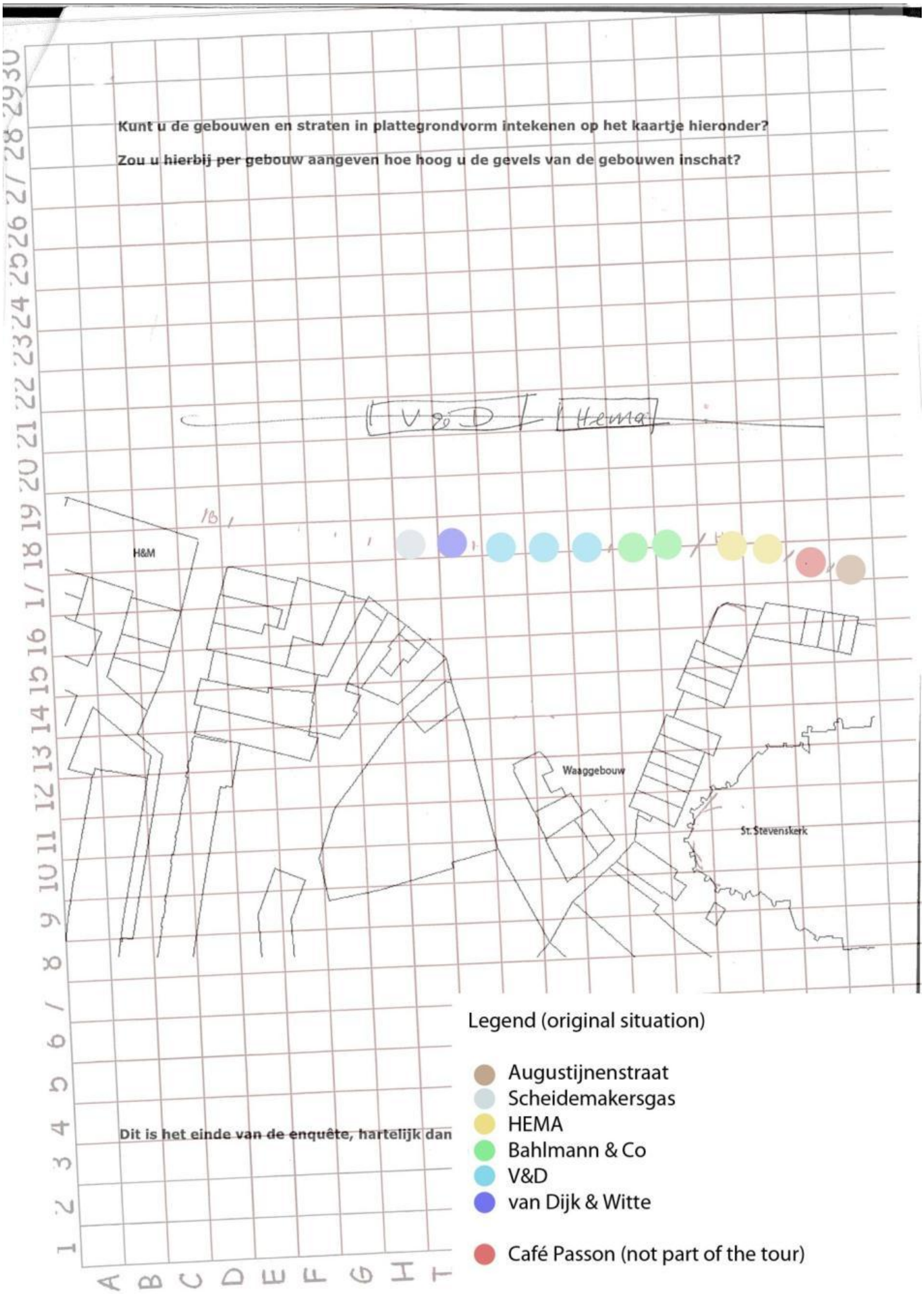


FIGURE 44 MENTAL MAP WITH GRID OVERLAY SHOWING ARELATIVELY POOR RESULT

APPENDIX XI AREA PERCEPTION

Equation 2: $Score\ after\ the\ tour\ [1 \dots 5] - Score\ before\ the\ tour\ [1 \dots 5] = Relative\ Change$

Equation 3: $\frac{SUM(relative\ change\ AR)}{10} = Relative\ change\ average\ AR$

Equation 4: $\frac{SUM(relative\ change\ Folder)}{6} = Relative\ change\ average\ folder$

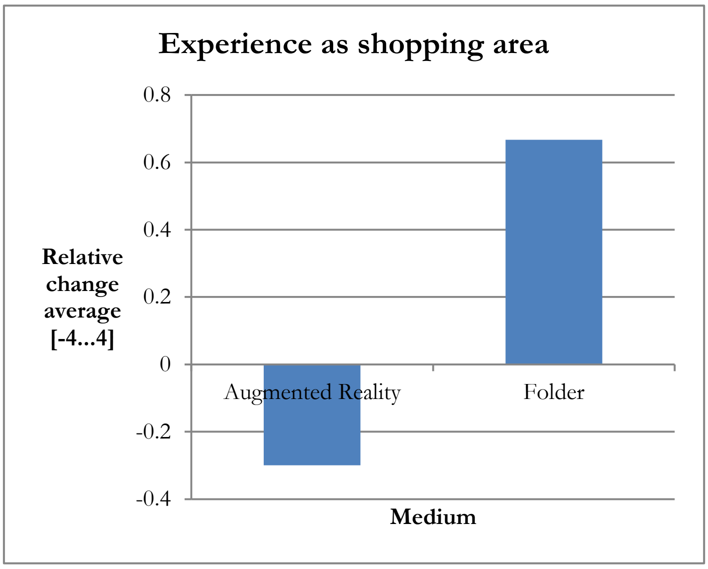


FIGURE 48 RELATIVE CHANGE IN AREA PERCEPTION FOR "SHOPPING AREA" PER MEDIUM. AR: N=10 | FOLDER: N=6.

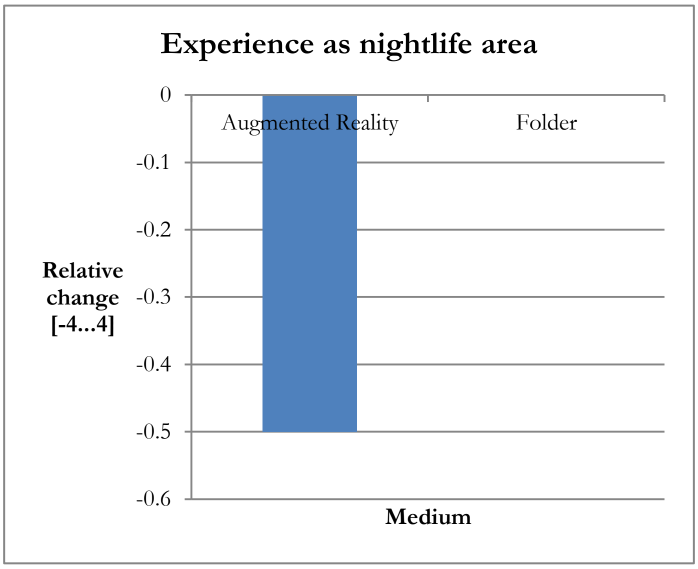


FIGURE 48 RELATIVE CHANGE IN AREA PERCEPTION FOR "NIGHTLIFE AREA" PER MEDIUM. AR: N=10 | FOLDER: N=6.

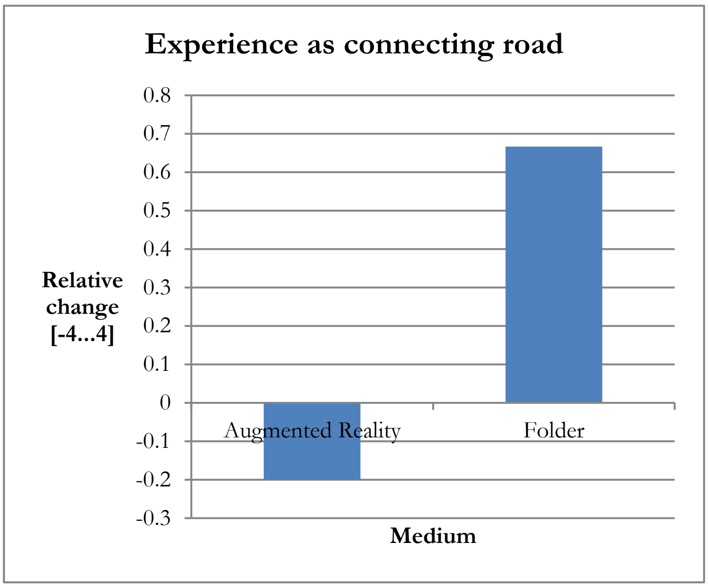


FIGURE 48 RELATIVE CHANGE IN AREA PERCEPTION FOR "CONNECTING ROAD" PER MEDIUM. AR: N=10 | FOLDER: N=6.

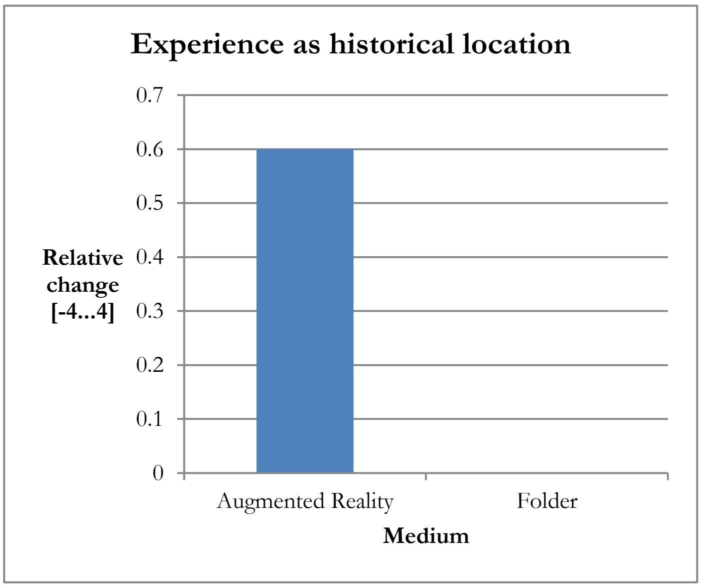


FIGURE 48 RELATIVE CHANGE IN AREA PERCEPTION FOR "HISTORICAL LOCATION" PER MEDIUM. AR: N=10 | FOLDER: N=6.

APPENDIX XII EVALUATION OF VISUALIZATION STYLES

Equation 5: $$\frac{SUM(evaluation\ score\ AR)}{10} = Average\ evaluation\ score\ AR$$

Equation 6: $$\frac{SUM(evaluation\ score\ Folder)}{6} = Average\ evaluation\ score\ Folder$$

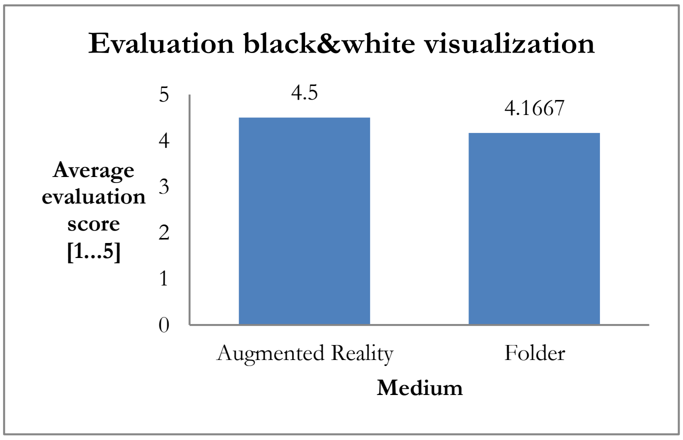


FIGURE 49 EVALUATION OF BLACK & WHITE PHOTOGRAPHS PER MEDIUM. AR: N=10 | FOLDER: N=6.

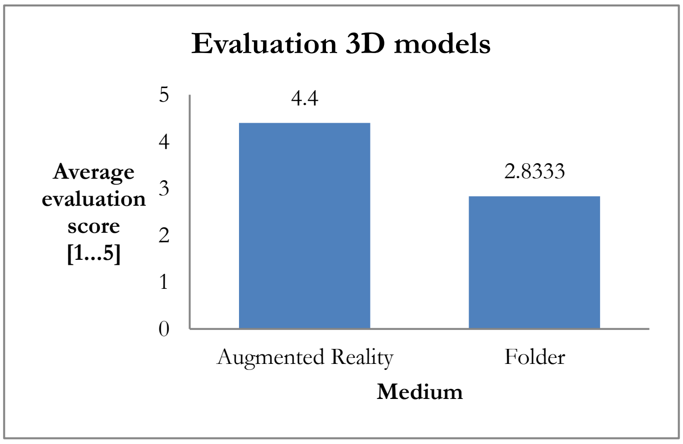


FIGURE 50 EVALUATION OF 3D MODELS PER MEDIUM. AR: N=10 | FOLDER: N=6.

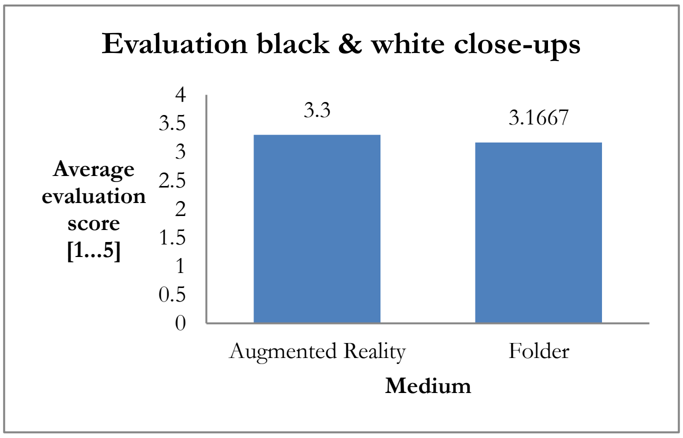


FIGURE 51 EVALUATION OF BLACK & WHITE CLOSE-UPS PER MEDIUM. AR: N=10 | FOLDER: N=6.

APPENDIX XIII SPSS RESULTS

TABLE 6 SPSS RESULTS SPEARMAN'S RHO CORRELATION BETWEEN MEDIUM AND ARCHITECTURAL KNOWLEDGE OF THE USER.

Correlations

			Medium	PostArch	PostBOL	PostASGM	PostASGMW	PostASGMD	PostASGMT	PostKennis NiveauScore	PostKennis Daadwerkelijk
Spearman's rho	Medium	Correlation Coefficient	1.000	-.447	-.360	-.257	-.410	-.376	-.292	-.449	-.603*
		Sig. (2-tailed)	.	.082	.170	.336	.115	.151	.272	.081	.013
		N	16	16	16	16	16	16	16	16	16

Table 7 Definitions of correlation matrix variables.

Abbreviation	**Definition**
Medium	Folder=1 / AR = 2
PostArch	After-Architectural knowledge
PostBOL	After-No. of buildings by Oscar Leeuw
PostASGM	After-No. of building styles
PostASGMW	After-Buildings in correct order
PostASGMD	After-No. Architectural details
PostASGMT	After-No. styles in correct timeline
PostKennisNiveauScore	After-Total architectural knowledge
PostKennisDaadwerkelijk	After-Total architectural knowledge corrected for knowledge base level

TABLE 8 SPSS RESULTS SPEARMAN'S RHO CORRELATION BETWEEN MEDIUM AND AREA PERCEPTION OF THE USER.

Correlations

			Medium	ARDiffFunc Winkel	ARDiffFunc Uitgaan	ARDiffFunc Doorg	ARDiffFunc Hist
Spearman's rho	Medium	Correlation Coefficient	1.000	-.445	-.302	-.447	.570*
		Sig. (2-tailed)	.	.096	.275	.095	.027
		N	16	15	15	15	15

TABLE 9 DEFINITIONS OF CORRELATION MATRIX

Abbreviation	Definition
Medium	Folder = 1 / AR = 2
ARDiffFuncWinkel	Change in area perception towards “shopping area”
ARDiffFuncUitgaan	Change in area perception towards “nightlife area”
ARDiffFuncDoorg	Change in area perception towards “connecting route”
ARDiffFuncHist	Change in area perception towards “historical location”

TABLE 10 SPSS RESULTS SPEARMAN'S RHO CORRELATION BETWEEN MEDIUM AND TOPOGRAPHICAL KNOWLEDGE OF THE USER.

Correlations

			Medium	TopoGas	TopoAug	NoBuildings Score	LocationScore	Topography Score
Spearman's rho	Medium	Correlation Coefficient	1.000	-.200	.333	.243	.255	.246
		Sig. (2-tailed)	.	.458	.207	.364	.341	.359
		N	16	16	16	16	16	16

TABLE 12 DEFINITIONS OF CORRELATION MATRIX VALUES.

Abbreviation	**Definition**
Medium	Folder = 1 / AR = 2
TopoGas	Whether user drew the "Scheidemakersgas"
TopoAug	Whether user drew the "Augustijnenstraat"
NoBuildingsScore	Accumulated score for no. of buildings identified
LocationScore	Accumulated score for no. of buildings placed at the right location
TopographyScore	Total score
FDR	Folder
AR	Augmented Reality

TABLE 11 COMPARE MEAN TOTAL TOPOGRAPHY SCORE BETWEEN MEDIUMS.

Report

TopographyScore

Medium	Mean	N	Std. Deviation
FDR	1.9167	6	3.04001
AR	2.9500	10	3.13980
Total	2.5625	16	3.04344

TABLE 13 SPSS RESULTS SPEARMAN'S RHO CORRELATION BETWEEN ARCHITECTURAL KNOWLEDGE OF THE USER AND PREVIOUS EXPERIENCE WITH SMARTPHONES, AUGMENTED REALITY AND AUDIO-TOURS.

Correlations

			PostKennis Daadwerkelijk	PostKennis NiveauScore	ExpSP	ExpAR	ExpAT	Medium
Spearman's rho	PostKennisDaadwerkelijk	Correlation Coefficient	1.000	.619*	.522	.288	.156	-.603*
		Sig. (2-tailed)	.	.011	.122	.420	.666	.013
		N	16	16	10	10	10	16
	PostKennisNiveauScore	Correlation Coefficient	.619*	1.000	.594	.234	.477	-.449
		Sig. (2-tailed)	.011	.	.070	.516	.164	.081
		N	16	16	10	10	10	16

TABLE 14 DEFINITIONS OF CORRELATION MATRIX VALUES.

Abbreviation	**Definition**
PostKennisDaadwerkelijk	After the tour: Total architectural knowledge corrected for knowledge base level: “corrected knowledge score”.
PostKennisNiveauScore	After the tour: “total knowledge score”.
ExpSP	Previous experience with Smartphones
ExpAR	Previous experience with Augmented Reality
ExpAT	Previous experience with Audio Tours

TABLE 15 SPSS RESULTS SPEARMAN'S RHO CORRELATION BETWEEN MEDIUM AND VISUALISATION STYLES

Correlations

			Medium	VSBWP	VS3D	VSBWCU
Spearman's rho	Medium	Correlation Coefficient	1.000	.236	.487	.043
		Sig. (2-tailed)	.	.380	.056	.874
		N	16	16	16	16

TABLE 16 DEFINITIONS OF CORRELATION MATRIX VALUES.

Abbreviation	**Definition**
VSBWP	Black and white photographs
VS3D	3D models
VSBWCU	Black and white close-ups

APPENDIX XIV PRINTED FOLDER