ARTree

DESIGNING & EVALUATING HANDHELD AUGMENTED REALITY ART

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Abstract

Augmented reality is a technology combining physical and virtual objects. This study aimes to explore the use of this technology in art. The prototype ARTree was developed through contributions from an artist, and consists of a physical tree and virtual objects representing the four seasons. A qualitative usability test was conducted where users were observed while interacting with ARTree, and expressed their thoughts and actions through the use of the think aloud technique. Findings from the evaluation were that users interact with AR art in an exploring way, experiencing it as a task. Findings also revealed that users find it more comfortable to interact with the paper markers that the 3D objects are connected to, than to move the tree and the branches.

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1 Introduction

This chapter introduces the idea of combining augmented reality and art through the development of ARTree to research how augmented reality can be used in art, and how users interact with augmented reality art. It also explains the research questions and activities that the study is based on as well as the organization of the thesis.

In our everyday lives we get more and more used to interacting with technology. We interact with computers in both our everyday and working lives, by using multimedia, cell phones, copy machines, kitchen appliances, driving our cars and so on, and new computer-based solutions get introduced to us on a regular basis. Because of this, it is important to design these interactive products so that the human-computer interaction is as easy and effective as possible, and gives a positive user experience.

People have been able to enjoy art in miscellaneous ways through the years. However, as technology continues to develop, so does art. Even though it has become more and more common to implement technology in art, as in the area of digital or interactive art, a person's role is still mostly that of being an audience, and not a user that interacts with a system.

1.1 ARTree

Augmented reality (AR) is a technology that uses a new and different kind of interface from what most users are used to today. It combines real and computer generated virtual imagery and can allow the user to interact with the virtual images using real objects (Zhou, Duh and Billinghurst, 2008). Real objects in this context can be for example paper markers. By using AR, a 3D- object can appear through an AR display, and AR allows the user to physically interact with the interface by positioning themselves to see the object from different angles, or through tangible paper-based interaction using markers. AR can also show 2D objects. This kind of AR most often offer extended information about the thing or place it is augmenting in form of pictures and/or text, and the amount of interaction here is limited. AR has become more common in the past few years, especially on mobile devices, where one can find several AR applications, most of them made for entertainment or information purposes.

As AR is a relatively new research field, there is still much we don't know about the technology's possibilities. The aim of this study is to explore the possibilities of AR by researching what happens when we introduce technology in an environment where most people are not used to having to interact with technology, and how to best design the user interface for this type of human-computer interaction. It was chosen to research AR in the field of art, and to do this, the goal was to create an artifact to research how AR can be integrated in art, and to use this artifact to research how users interact with AR art.

An artist interested in learning about how to implement technology in her art was included in the process of creating the artifact. This was to ensure user involvement throughout the design process, as well as to give the project a realistic foundation in the field of art, in addition to information science. Through brainstorming sessions (described in section 4.1.1), together we came up with an idea for an artwork, and a functioning prototype of this work of art was created for this study. The prototype, which is in form of a tree, was given the name ARTree, to imply that the tree is both AR and art. This study can be seen from both an art perspective, as well as from a human-computer interaction perspective. Although art is very much a part of this study, the latter is the focus throughout this thesis.

1.2 Research questions

The main outcomes of this study are the prototype itself and experiences made from the process of creating it, as well as the findings from the evaluation done by the end of the process. Through the design process, different considerations had to be made to unite augmented reality and art. Producing ARTree in a material that encouraged touching and interacting with the artwork, having AR markers that were movable, as well as allowing the users to view the augmentations through handheld monitors, provided possibilities for interacting with AR art in several different ways. When evaluating ARTree, two things were highlighted: human-computer interaction in AR art, where the users interact as users instead of an audience, which is further addressed in chapter 2, as well as the user experience of augmented reality art.

The focus for this study is the following research questions, and their belonging research activities:

1. How can augmented reality be used in art?
   - ⇒ Research activity: Develop a prototype of augmented reality art
2. How do users interact with augmented reality art?
   - ⇒ Research activity: Evaluate the interaction with augmented reality art
3. How do users experience augmented reality art?
   - ⇒ Research activity: Evaluate the user experience of AR art

1.3 Organization of the thesis

Each chapter begins with a short description of the chapter's contents, and ends with a summary of the chapter. The following chapter contains background information on the research fields that this study is based on through a review of relevant literature and a discussion of ARTree seen in the context of this. Chapter 3 explains which methods have been used as a framework for the study as well as for the evaluations, specifically design-science research and qualitative evaluations using the think aloud technique. Chapter 4 documents the process of creating the prototype ARTree from beginning to end, as well as giving a review of the tools used during this process. Chapter 5 explains how the evaluations and pilot study were planned and conducted, and which findings the evaluations resulted in. Chapter 6 concludes the thesis by reflecting on the study and proposing further research for ARTree, as well as the area of augmented reality art.

1.4 Summary of the chapter

This chapter introduced the aim of the study and the research questions and activities that were set. The prototype, named ARTree, was introduced, and an introduction to the technology augmented reality was given. The next chapter contains a review of the relevant research fields for this study, and ARTree is placed in the relevant contexts.

2 Background and related research

This chapter gives insight to the research fields that serve as a background for this study, which are human-computer interaction, digital and interactive arts and augmented reality. Relevant literature and previous research is presented and discussed, and ARTree is seen in the context of this.

2.1 Human- Computer Interaction

According to Anders Fagerjord (2006), it is impossible to know what is meant by the word *interaction* without being given a definition of it in a set context, as the extent of the phrase has become so vast over the years. Therefore, to be able to discuss human-computer interaction, there is a need to clarify what interaction is in the context of this study. Even though merely pressing the power button on your computer can to some degree be considered as interacting with the computer, nowadays interaction usually requires other actions from both the user and the system.

Jens F. Jensen (1998) conducted a review of definitions of what interaction is, and found that most definitions were too rigidly based on specific technologies. Jensen therefore proposes a broader definition of interactivity, which is that it can be said to be “a measure of a media’s potential ability to let the user exert an influence on the content and/or of the mediated communication” (Jensen, 1998: 201). Sheizaf Rafaeli (1988: 119) offers a more specific definition of what interaction is, by dividing interaction into three levels:

> “…two way (noninteractive) communication, reactive (or quasi-interactive) communication, and fully interactive communication. Two-way communication is present as soon as messages flow bilaterally. Reactive settings require, in addition, that later messages refer to (or cohere with) earlier ones. Full interactivity (responsiveness) differs from reaction in the

> incorporation or reference to the content, nature, form, or just the presence of earlier reference."

In this study, *interaction* is understood as what Rafaeli (1988) calls *full interactivity* or *responsiveness*, requiring a two-way communication between the user and the system, where new actions from either parts in some way reflects the relations between earlier actions.

2.1.1 History of human-computer interaction

Even though human-computer interaction (HCI) as we understand it today is a rather new field, people have interacted with computers in some way or another since they were invented. Over time, the interaction has changed, requiring different kinds of skills from the users. According to Dourish (2004), historically there have been four phases of development within HCI: electrical, symbolic, textual and graphical forms of interaction.

The electrical phase consisted of interacting with analog computers in form of manually configuring the machine's circuits. The symbolic phase introduced interaction on a more abstract level, where users interacted by using early programming languages called assembly languages, which e.g. could be encoded on punched cards. The textual phase had a similar kind of interaction as the symbolic phase, but here the interaction was more like a dialogue – the user instructed the computer by entering commands, and thereafter received responses from the computer. This can be said to be the origin of interactive computing. The graphical phase opened up for two-dimensional interaction, spreading the information out on the screen as opposed to a one-dimensional stream of text across the screen. The graphical phase allowed for new interaction techniques, such as for example direct manipulation. This phase was also the beginning of today's interfaces, among them augmented reality. HCI has many related research fields, some of them are cognitive science, ergonomics, computer-supported cooperative work, product design and information systems, which all falls under the umbrella term *interaction design* (Sharp, Rogers and Preece, 2007).

2.1.2 User experience

According to Sharp, Rogers and Preece (2007: 15), user experience is central to interaction design, and is about “how people feel about a product and their pleasure and satisfaction when using it, looking at it, holding it, and opening or closing it”. In other words, user experience is highly individual, and while one user might experience a product as being easy to interact with, beautiful to look at and fun to use, another user might think the exact opposite. Because of this, it is important to be aware of that “one cannot design a user experience, only design *for* a user experience” (Sharp, Rogers and Preece, 2007: 15). In his book *“Emotional design: why we love (or hate) everyday things”,* Donald A. Norman (2004) claims that we find products easier to use when they make us feel better. Because of this, a goal in the development of ARTree has been to design it for a good user experience that makes the users feel good while interacting with it.

2.2 Digital and interactive art

According to Edmonds, Turner and Candy (2004), different kinds of art forms have been used in digital arts, such as painting, film and performance. As early as in 1973, Cornock and Edwards (1973) divided artworks into three categories based on the level of interaction they allowed:

1. The static system: Most artworks falls into this category, where the artwork cannot be changed or adjusted by a participant.
2. The dynamic passive system: An artwork that can change on counts of the artist or the environment, but not a participant.
3. The dynamic-interactive system: The participant can interact with the artwork and change it.

ARTree falls into the third category, by being dynamic and allowing for user participation through rearranging the AR markers. Edmonds, Turner and Candy (2004) claim that even though there are amounts of available tools for creating digital and interactive art, there is a need for the artist to have some knowledge of programming to have full artistic control over the artwork, as being dependant on a technologist can give the artist the feeling of giving up control over their artwork. ARTree is a prototype of an idea of an artwork that was conceived during brainstorming sessions (see section 4.1.1) as a collaboration between technologists who are also usability experts, and an artist, therefore the initial idea was consistently refined to be valid both from an artistic point of view as well as from a technological point of view. This was a way to make sure that everyone included had some amount of control over what was being created, and the outcome was a result of compromises that everyone could agree on. This may be a solution to the problem Edmonds, Turner and Candy (2004) describes.

2.2.1 Audience participation

According to Edmonds, Turner and Candy (2004), there has been a big interest in audience participation in art since the 1960s. According to Todd Winkler (2000: 1), audience participation is what makes interactive art so interesting:

> "What separates interactive installations from other types of art installations of interactive performances is that the work is only realized through a participant's actions, interpreted through computer software or electronics, and those actions do not require special training or talent to perform. All of this suggests a new social and artistic dynamic that is unique to interactive installations, requiring the audience to physically participate in creating their own artistic experience. "

There are two kinds of users for interactive art, ARTree included. One kind of users are the end users, who has no previous knowledge of how to interact with the specific artwork, but will indeed do so, and through being more active users, their role is expanded to also include an artistic position. The other kinds of users are the artists, who can again and again create new versions of their own art, just like the regular users. In other words, in the context of interactive art, the user also becomes an artist, and the artist also becomes a user.

There are many different terms used for describing the person who interacts with an artwork or other media, such as audience, spectator, participant, and user. In HCI and interaction design, it is common to use the term *users*, and as this study is seen from an interaction design point of view, that is the term that will be used here.

2.3 Augmented reality

Augmented reality has its origin in Ivan Sutherland's (1968) *head-mounted three dimensional display,* where the users could see 3D objects visualized around them, much like in virtual reality. Virtual reality is the term used when the interaction is with a fully artificial environment. Virtual environment (VE) is also a commonly used term for this kind of interface (Sharp, Rogers and Preece, 2007). According to Milgram and Kishino (1994), both AR and VR is part of a "virtuality continuum" (see Figure 1), with an environment consisting of only real objects at one end, and an environment with only virtual objects on the other. *Mixed reality* (MR) is the term used for environments that combine real and virtual objects, such as augmented reality.

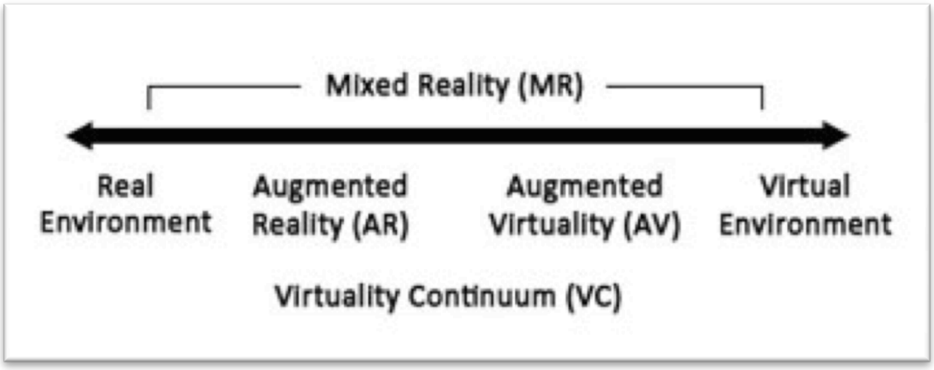

Figure 1: Virtuality continuum[1]

Costanza, Kunz and Fjeld (2009: 48) describes MR as systems where “users perceive both the physical environment around them and digital elements presented through, for example, the use of semitransparent displays”. They also mention that “MR includes systems in which the virtual aspects are dominant as well as those in which the physical reality is dominant. Within this range, augmented reality has more physical elements than virtual elements”. Costanza, Kunz and Fjeld (2009) highlight that many MR systems act more like VR, in the way that the virtual elements are more important than the physical ones, and that in many AR systems the virtual elements are to a low degree related to the physical reality. To specify, MR is any mix of virtual and physical reality. AR is a kind of MR, where the physical part is most important, and the virtual part ideally should be related to the physical elements. This can be understood as in AR, the physical element should be able to stand alone, and the virtual elements are merely an addition – an augmentation.

2.3.1 Augmented reality displays

There are different kinds of AR displays, the most common ones are projector-based displays, handheld displays and Head-Mounted Displays (HMD). Which type of display to use depends on the settings in which the display will be used. Projector-based displays can make the augmentation visible in a larger scale to multiple users,

[1] Virtuality continuum in Milgram and Kishino (1994)

while handheld displays are mobile and can be personal, such as e.g. a mobile phone. HMDs might make the experience of AR seem more real to the user as the user is more “locked in” on the AR-view than he would be while using a projector or a handheld device (Zhou, Duh and Billinghurst, 2008).

HMDs were the start of both AR and VR through the work of Sutherland (1968). These were for a long time relatively big constructions and heavy for the user to wear, as the user has to wear them continuously while interacting with a system. Through the years, and development of new technology, HMDs have become both smaller and lighter, but there is still a way to go. HMDs need to have a screen and a camera, and therefore there are limits for how small and lightweight they can be, even with today’s technology. HMDs also have its limits when it comes to collaborative work and supporting multiple users (Zhou, Duh and Billinghurst, 2008).

As it has become more and more common to have cameras in mobile phones and other small handheld devices, augmented reality developers have started to use such handheld devices instead of having to use the large, expensive and often uncomfortable head mounted displays (Schmalstieg and Wagner, 2007). According to Zhou, Duh and Billinghurst (2008: 198), handheld displays are “minimally intrusive, socially acceptable, readily available and highly mobile”.

Because of this, it was chosen to use a handheld device in the form of a handheld monitor with a camera attached to its back to display the augmented reality objects in this study, hoping that it would be less intimidating for users to pick up a handheld monitor instead of putting on a pair of HMDs. By using a handheld device, the audience can pick up the monitor and hold it in front of the artwork to interact with it and see the AR objects. They are also able to walk around the artwork holding the monitor in different angles to get a better view of each of the objects.

2.3.2 Previous research

Augmented reality has been researched and experimented with in a number of fields, such as in military, gaming, entertainment, and commercial applications (Azuma et al., 2001). Other areas includes learning, for example the development of the Multimedia Augmented Reality Interface for E-Learning (MARIE) developed for engineering education (Liarokapis et al., 2002), training and maintenance in industrial contexts (Schwald and de Laval, 2003), and in medicine. Shuhaiber (2004) presents an overview of research on AR in surgery, and mentions among other things how AR have been used in neurosurgery, which is mostly by imposing a 3D image of the brain onto the real brain, so-called *interactive image-guided neurosurgery*. In addition to neurosurgery, AR has also been used in general surgery, for example by adding a 3D image of a tumor onto live video, to visualize the exact location of the tumor.

2.3.3 HCI principles in AR

In HCI and interaction design, we design and evaluate on the grounds of design principles and usability goals. Dünser et al. (2007) suggest applying HCI principles when designing AR systems also, as there are few general design principles specifically made for AR. Dünser et al. (2007) have collected well-known design principles and usability goals from different sources, and some of these have been applied in the creation and evaluation of ARTree. The principles used here are affordance, reducing cognitive overhead, and learnability, which are all further explained in the relevant contexts in this thesis.

2.3.4 Augmented reality in art

Some research in the field of AR and art has previously been conducted, but this is still a very new research field, without any clear definitions of what can actually be called AR art. The need for any additions to this research field is obvious. Christine Ross (2009) conducted a review of what she calls augmented reality art, and mentions among other things Usman Haque's[2] *Evoke. Evoke* is a projection onto the façade of the York Minister cathedral, which is triggered and changed by the surrounding noises. While this piece of art is most certainly interactive, as well as an augmentation, does it mean that it can be called augmented reality? The artist himself used the term "*interactive projection"*, which can be said to be a much more accurate description of the artwork. Ross (2009) continues to mention artworks with augmented light, sounds and so on, triggered by the weight, chatter, as well as the presence and proximity of the users, which can be said to be more or less unintentional interaction by the users.

More relevant is the E-Tree, "a virtual tree structure whose growth and evolution reflects the perceived affective response from the spectator throughout interaction (e.g., in terms of interest or positive and negative judgment)" (Gilroy et al., 2007: 1). The E-Tree "grows" from a marker, and its color, growth, branching and so on is a result of the user's interaction. While E-Tree is referred to as AR art, only the AR object is art, and this is visualized onto a real environment. In comparison, ARTree combines virtual art objects with physical art, and the combination of the two is seen as AR art. Gilroy et al. (2007) also refers to the user as a "spectator", even though it is possible for the user to interact with E-Tree by moving the markers and so on. ARTree highlights the fact that the user participates in the design of the artwork, and becomes more than just a spectator.

2.3.4.1 Criteria for AR art

Because of the differences discovered in previous research on the subject when it comes to definitions of what augmented reality art is, it is relevant to define AR art

[2] More info on Evoke can be found at http://www.haque.co.uk/evoke.php

in the context of this study. In this study, for something to be called AR art, it must fulfill these criteria:

- Augmented reality art is the combination of a physical artwork and a virtual augmentation of this artwork
- The virtual augmentation needs to be related to the real art
- The interaction between the user and the artwork should be deliberate
- Through interacting with the AR art, the user should be able to change the artwork so that each user takes part in creating their own version of the artwork

The reason for defining that the virtual and real art should be related is to make it clear that the virtual art is an augmentation of the real art, and not just a random virtual object visualized onto a real object. The users should also be aware of that they are taking on the role of the artist, and intentionally interact with and change the AR art to look the way they want it to, in coherence with Cornock and Edmonds's (1973) definition of a dynamic-interactive system. Unintentional interaction with AR art can of course cause users to interact intentionally after they see what happens when they first interact unintentionally. However, the art should provide some clues for the user for how to interact with it so that the initial interaction requires the users' attention and requires them to make choices, resulting in a personalized version of the artwork created with intention and not coincidences.

The E-Tree created by Gilroy et al. (2007) fails to fulfill the first two criteria. Only the virtual object can be seen as art, not the marker or the surface it is placed upon. Also, there are limited relations between the art and the physical reality, and the E-Tree seems to fall better under the definition of mixed reality as Costanza et al. (2009) describes it.

2.4 Summary of the chapter

This chapter gave a review of the research fields Human- Computer Interaction, digital and interactive arts and augmented reality. ARTree was discussed in the light of previous research, and new criteria for AR art were proposed. The next chapter elaborates the research questions and activities for the study that were introduced in chapter 1. In addition, the study is discussed as design science, qualitative evaluation is introduced, and different approaches to the think aloud technique is presented.

3 Methodology

This chapter explains the methodological foundations for this study. First, the research questions are presented and explained. Then, design science research is introduced, the project is classified as such, and guidelines for doing this kind of research are presented and adjusted for use in this context. Last, the chosen evaluation approach and methods are introduced.

3.1 Research questions

When deciding which research and evaluation methods to base this study on, the focus was on the research questions, and to choose methods that would answer these sufficiently.

The following are the research questions for this study:

1. How can augmented reality be used in art?
2. How do users interact with augmented reality art?
3. How do users experience augmented reality art?

As augmented reality art is a relatively new field, part of the aim of this study, which is reflected in research question one, was to explore the possibilities of how one creates AR art, how AR can be used in art as well as which possibilities using AR in art opens up for when it comes to audience participation. The latter brings us to research question two. From observing the test users, one can learn about how the users interact with AR art, and with it markers, as well as how handheld devices work in the context of AR art. It is especially interesting to observe users unfamiliar with AR to see how they approach interacting with the art. When it comes to user experience, this is hard to measure, as the user experience can differ from each user. However, through the use of evaluation methods, an attempt will be made to get knowledge about how the users experience AR art.

The following research activities were carried out in order to answer the research questions:

- Develop a prototype of augmented reality art
- Evaluate the interaction with and user experience of augmented reality art

The prototype was created to learn about the process of creating AR art, as well as to have an appropriate artifact to use during the evaluations. Also, both through the creation and the evaluation of the prototype, it is possible to determine the feasibility of AR art. Evaluating the prototype can highlight issues with the prototype, as well as areas for further research, but most importantly it reveals how users interact with the prototype. The development of the prototype is documented in chapter 4, and the evaluations in chapter 5. Further research is suggested in chapter 6.

3.2 Design-science research

According to Hevner et al. (2004), the research on information systems can be divided into two main paradigms: behavioral science and design science. While the behavioral science paradigm is focused on explaining and predicting human or organizational behavior, the design science paradigm evolves around creating and evaluating innovative IT artifacts to better understand a problem domain and its solution. As this project evolves around designing and evaluating a very innovative IT artifact, categorizing the project as design science seems natural. Hevner et al. (2004) divides artifacts into constructs, models, methods and instantiations. While a construct is the vocabulary and symbols that are used for defining problems and their solutions, a model is a set of constructs, a method is a way to build models, and an instantiation is a way of explaining the feasibility of the design process and the product itself. ARTree falls under the latter category.

Hevner et al. (2004) proposes seven guidelines for design-science research, and these guidelines have been followed throughout this study. However, the guidelines were developed with the purpose of being used in an entirely different context, which is to solve business problems in an organizational context, and therefore they do not always apply well to this study. The process for this study have however been inspired by design science, and section 3.2.1 contains a discussion of how the guidelines can be relevant in this context. Below are the design-science research guidelines as described in Hevner et al. (2004):

Guideline	Description
Guideline 1 - Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2 - Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3 - Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4 - Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or methodologies.
Guideline 5 - Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6 - Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7 - Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Table 1: Design-science research guidelines[3]

[3] Design-science research guidelines cited in Hevner et al. (2004:83)

3.2.1 Relevance of the guidelines

As mentioned above, this study follows the first guideline, *design as an artifact*, in the way that an artifact in form of an instantiation was created. Guideline 2, *problem relevance*, is not as relevant to this study as the goal was not to solve any business problems. In this study, the goal is not to solve a problem at all, but there is a goal of finding answers for how to explore the use of new technology. This has however been done by developing a technology-based solution, and can be said to be quite relevant in both the field of AR as well as in art. The third guideline, *design evaluation*, is more relevant, as ARTree was evaluated through rigorous methods. *Research contributions*, which is the fourth guideline, is also relevant to this study, and the research contributions are both ARTree as well as this thesis. This study has followed the fifth guideline, *research rigor*, by using rigorous methods both to create and evaluate ARTree. Designing the artifact was an iterative process, and ARTree was constantly improved throughout the design process until a solution that was according to the requirements was reached, following the sixth guideline, *design as a search process*. Guideline 7, *communication of research*, must also be adapted for the context of this study, as there are no desires to present this thesis to a management-oriented audience. However, there was a need to present the study as effective as possible, through this thesis. Although these guidelines do not apply perfectly to this study, the core of design-science research is about doing research through creating something, which is also what has been done for this study.

3.3 Evaluation

In interaction design, evaluation is conducted both during the design process and to evaluate whether or not a product is for example effective, easy to use, or provides a good user experience (Sharp, Rogers and Preece, 2007). According to Sharp, Rogers and Preece (2007), there are two kinds of evaluations: summative and formative. While the former is conducted using a finished product to check that certain standards have been reached, the latter is conducted during the design process to see if the product meets the user's needs. The evaluation of the final prototype can be said to be a formative evaluation, seeing as ARTree is still a prototype. This section introduces the evaluation approach and methods used during the evaluations of ARTree, and in chapter 5 it is documented how the methods have been applied.

There are three main evaluation approaches: usability testing, field studies and analytical evaluation. Usability testing is usually conducted to measure how users perform on given tasks, as well as to uncover if the product that is being tested is usable by it's target group. These kinds of evaluations are often conducted in a laboratory setting where they cannot be interrupted. Observation and video recordings are commonly used in usability testing. Field studies are conducted in natural settings and are often the chosen evaluation approach when the goal is to see how a product affects the users in their everyday lives. Analytical evaluations in form of for example cognitive walkthroughs or heuristic evaluations are mainly conducted without involving users, relying on experts to do the evaluation (Sharp, Rogers and Preece, 2007).

As there was an intention to involve users, both novices and experts in form of the artist throughout the process of developing ARTree, doing an analytical evaluation solely with experts or expert users was not an option. Doing a cognitive walkthrough with both novices and an expert was considered, but this would require the test users to perform given tasks. As one of the goals for the evaluation was to see if ARTree offered some kind of affordance to the test users, and to see how they interacted with ARTree independently with limited instructions, it was decided to not have the test users perform any set tasks. Affordance was introduced as a design principle by Donald A. Norman in "The psychology of everyday things", and refers to the "perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used" (1988: 9). ARTree was also not physically big enough for a field study to be realistic for the users, hence conducting a usability test was the best choice for ARTree. As mentioned in section 3.1, the focus of the evaluation consisted of two parts:

1. Evaluating how the users experienced walking around with the hand-held monitor and interacting with the prototype
2. Evaluating how the users experienced the prototype

3.3.1 Qualitative evaluation

According to Adams, Lunt and Cairns (2008: 138), the emphasis in qualitative research is “not on measuring and producing numbers but instead on understanding the qualities of a particular technology and how people use it in their lives, how they think about it and how they feel about it”. As the evaluation of ARTree was in part about uncovering the feasibility of AR in art, this coheres with doing a qualitative evaluation. To get knowledge about the user’s previous knowledge about AR and digital and interactive arts, it was decided to hand out a questionnaire before each evaluation session. These questionnaires (further described in section 5.1.4) contained questions that gathered both quantitative and qualitative data. According to Sharp, Rogers and Preece (2007), analyzing qualitative data begins with trying to look for patterns, some of which may have already been clarified by the chosen observation framework. They also highlight the importance of having clear goals for the study, and to especially look for issues concerning these goals.

3.3.2 Think aloud

Observing users during an evaluation can be a fruitful way to see how users interact with a prototype, but at the same time knowing which cognitive processes are taking place will give the researcher a broader understanding as to how the user responds to the prototype. The think aloud technique is to ask users to explain out loud what they are thinking and doing while interacting with a prototype or a finished product. According to Nielsen, Clemmensen and Yssing (2002), Karl Duncker’s work within experimental psychology in 1945 is the origin of the think aloud technique, but the work of Ericsson and Simon originally from 1984 is most commonly referenced. Ericsson and Simon (1993) focus on verbalization, divided into three types after when they occur:

1. While information is attended
2. While information is still in short-term memory
3. After the completion of the task oriented process

The first type of verbalization is a direct articulation of what the person is seeing or thinking. The second is an explication of stored information, where the person needs to transform the impressions into words before verbalizing them. The third is a retrospective kind of verbalization, requiring the person to process the information before verbalizing it. Ericsson and Simon (1993) recommend using the first kind for think aloud sessions, and see the third kind as unreliable data. Boren and Ramey (2000) highlight the fact that the third kind of verbalization is what occurs when a facilitator prompts or converse with the test user, which is quite common while using the talk aloud technique.

Although the think aloud technique was originally developed for psychological research, it is commonly used to evaluate human-computer interfaces. According to Jacob Nielsen (1993), the advantage of using the think aloud technique is that one can collect substantial qualitative data from a small amount of users. HCI researchers have tailored the technique to their needs, and many different approaches to the technique have been discussed, especially when it comes to the role of the facilitator. Using the think aloud technique during an evaluation can be somewhat demanding for the users, as they are not used to "thinking aloud". Users may also feel like they are being observed and judged, and make excuses for interfaces malfunctioning, as well as fail to explain their actions and thoughts, leading to complete silence. One way of making the situation more comfortable for the users, and to avoid silence, is to have two users do the evaluation together, letting them talk to each other (Nielsen, Clemmensen and Yssing, 2002).

Another way of avoiding silence as suggested by Buur and Bagger (1999), is to move the facilitator into the lab together with the user, making him or her an active dialogue partner. Buur and Bagger (1999) also suggest bringing the designer into the room, encouraging a discussion between the user(s) and the designer as a way of involving users and listening to their ideas.

Boren and Ramey (2000) emphasize the fact that inconsistencies between theory and practice when it comes to using the think aloud technique are common. They have found that even though Ericsson and Simon's work is often cited as the model for think aloud, usability practitioners fail to follow the model in practice. Claiming that there is a lack of a methodological consistency in using think aloud in usability testing, they highlight the need for a well-working framework for simplifying the comparison of results from usability tests, and to be able to teach a standard to newcomers.

Boren and Ramey (2000) propose using speech communication as a theoretical basis for using the think aloud technique in usability testing. They mention that users can find it hard to try and imagine that they are speaking their thoughts out loud to an empty room, clarifying that while using think aloud in usability testing, there is always a speaker (the user), as well as a listener (the usability practitioner or facilitator). However, their roles may be somewhat asymmetric – the speaker does most of the talking, and the listener's level of responding is varying. The evaluations of ARTree followed Boren and Rameys (2000) proposal of an alternative to Ericsson and Simon's (1993) model, the use of this is further elaborated in section 5.1.1:

1. Setting the stage: The usability practitioners should make sure that the test users are aware that it is the product being tested, not them, and they should set the roles of the test user being the primary speaker, and the usability practitioner the primary listener.

2. Nature of speech: Acknowledging the test user by saying “OK”, “mm”, “hm” and so on, preferably using an interrogative intonation, which can let the test user understand that he or she is to continue talking.
3. Required interaction: For example if there is a malfunction in the system, the asymmetrical dialog becomes more of a symmetrical dialogue while the problem is being solved, and then goes back to being asymmetrical again when the problem has been fixed. The practitioner can also interact more with the test user if he or she needs to for example remind the test user to use all of the system’s functions that were to be tested.
4. Additional information: Practitioners can ask the test users to elaborate on comments, as well as ask direct questions after the task is completed, or during a debriefing after the evaluation.

3.4 Summary of the chapter

In this chapter, the research questions for this study were elaborated on and it was discussed how these could be answered. All though the study is classified as design science research, the relevance of the guidelines proposed by Hevner et al. (2004) were discussed and thereby needed to be adjusted to apply for this study. Usability testing was decided as the most appropriate evaluation approach, and observation along with the think aloud technique were chosen as the evaluation methods. Boren and Ramey’s approach to the think aloud technique was chosen for the evaluations of ARTree. The next chapter describes the development process of creating the prototype ARTree.

4 Development of ARTree

This chapter documents the development of the prototype from beginning to end. From gathering and setting requirements to choosing the right software both for augmented reality and 3D modeling, in addition to explaining the choices made during the prototyping process, both for the tree, the 3D objects, and the markers.

The first guideline for design-science research by Hevner et al. (2004) states that one should provide a viable artifact. The main reason for producing an artifact in this case is the need for something for users to interact with during evaluation. The artifact in this project consists of two parts; a prototype for an artwork, and 3D objects. Together, these two make the artifact called ARTree. The fifth guideline from Hevner et al. (2004) states that the development and evaluation of the artifact should be conducted using rigorous research methods. The last chapter described the evaluation methods used, and this chapter documents the methods used for creating the prototype. The interaction design process for designing ARTree has followed Sharp, Rogers and Preece's (2007) framework, divided into these four activities:

- Identifying needs and establishing requirements for the user experience
- Developing alternative designs that meet those requirements
- Building interactive versions of the designs
- Evaluating what is being built throughout the process and the user experience it offers

4.1 Requirements

A requirement explains what the product should do, or which qualities it should have. Before you can design and develop a product, it is important to have requirements for this product, which comes from understanding the setting in which the product is intended to be involved (Robertson and Robertson, 2006). There are different ways of establishing requirements, e.g. by doing interviews, using focus groups, questionnaires, observing users, brainstorming, constructing scenarios and so on (Sharp, Rogers and Preece, 2007).

4.1.1 Brainstorming

According to Robertson and Robertson (2006), brainstorming is a technique for discovering and determining requirements as well as the people involved in a process. They also claim that brainstorming can be a way of inventing, useful for collecting ideas that can lead to a better product, and that the aim is to be as imaginative as possible and to generate as many ideas as possible. As this project did not have a specific user group, and was intended to be a rather innovative one where there were no established rules or conventions for how things should be, other than that the focus was on exploring new ways of using new technology, using brainstorming to establish requirements seemed fitting. Robertson and Robertson (2006: 118) mention a few rules for brainstorming sessions. Excluding the rule about pulling a word randomly from a dictionary, each of these rules were taken into account during the brainstorming sessions for ARTree:

- "Participants in the brainstorming session should come from a wide range of disciplines, with as broad a range of experience as possible. This mixture of backgrounds brings many more creative ideas to the fore.
- For the moment, suspend judgment, evaluation, criticism, and, most importantly, debate. Simply record requirements as they are generated. The practice of not stopping the flow is the fastest way to develop a creative and energized atmosphere for the brainstorming group.
- Produce lots of ideas. Come up with as many ideas as possible. Quantity will, in time, produce quality.
- Try to come up with as many ideas as you can that are unconventional, unique, crazy, and wild. The wilder the idea, the more creative it probably is, and often the more likely it is to turn into a really useful requirement.
- Piggyback a new idea onto an old one. That is, build one idea on top of another.

- Write every idea down, without censoring.
- If you get stuck, seed the session with a word pulled randomly from a dictionary, and ask participants to make word associations that have some bearing on the product. That is, generate ideas using the word as a springboard.
- Make the session fun. You cannot mandate creativity; you have to let it come naturally. You won't see many ground- breaking ideas if the boss is on the session and says something like, "I only want to hear ideas that are marketable."

The participants for the brainstorming sessions were the artist Jannicke Olsen, research fellow Tor Gjøsæter and I. While Gjøsæter and I have somewhat similar backgrounds within computer science and interaction design, Olsen has a completely different approach to things, which was very interesting during the brainstorming. Including Olsen in the brainstorming sessions was also a way of ensuring an early focus on user-centered approach. Gathering data for setting the requirements was an iterative process. We had several sessions, all documented in form of taking notes, one also by video recording. In addition to this, we also did some sketching, which was an important way of communicating ideas to the other participants (see figure 2). A vast amount of ideas came up during the brainstorming sessions, and most of these were later identified as suggestions for further research, as there was not sufficient time to use all of them at this point. Some ideas were refined, and focused upon during later sessions. From the notes taken during the brainstorming sessions, a set of final requirements for ARTree was extracted.

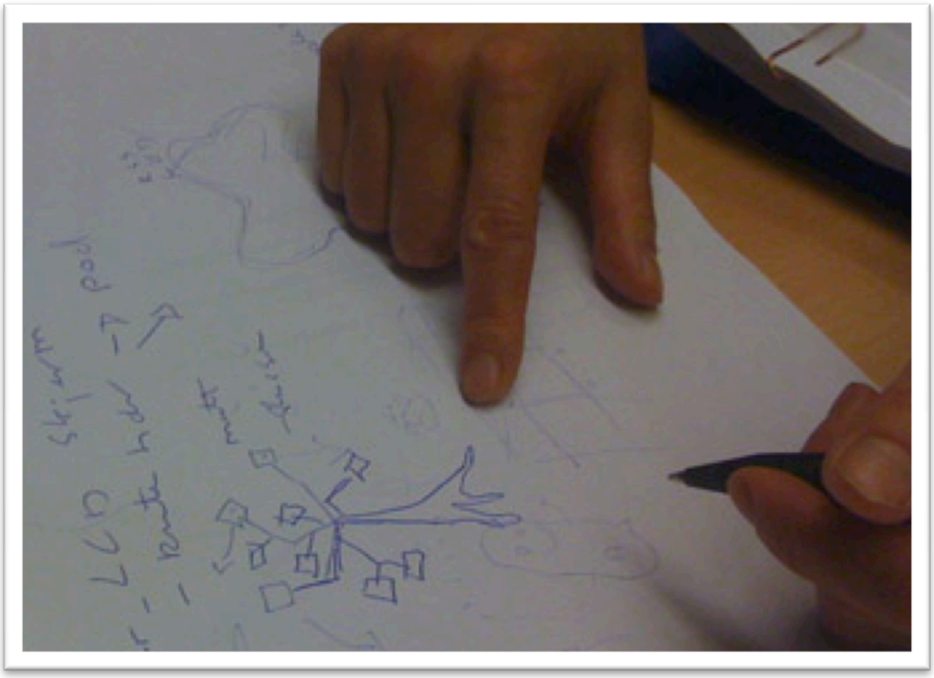

Figure 2: Sketching during a brainstorming session

A premise for the brainstorming sessions was that augmented reality should be used in an art project. It was decided that a functional prototype should be developed, in form of a tree with 3D objects that would be visible through a handheld device. It should be possible for users to interact with the art, both by moving themselves and elements of the artwork. Olsen had a vision about what kind of augmentations the tree as a finished artwork should have using AR. Her vision had three parts; the tree should somehow wish the user a good day, it should highlight issues concerning climate changes, and it should show the tree during the four seasons. The latter was the one that was chosen to be developed for the prototype, as this was the part that was most interesting from an interaction design point of view in the way that it could easily be transferred to specific objects and markers. Also, as art can sometimes confuse its audience, and as the purpose of the prototype was to evaluate user experience with AR in art, it was requested to make the interface as understandable as possible, so that the user would focus on interacting with ARTree, and not be distracted with confusing or unclear elements. The prototype was during the requirements process given the name ARTree, indicating that this is a project concerning both AR and a tree, as well as art.

4.1.2 Requirements for ARTree

The requirements that were discussed during the brainstorming sessions were mostly in regards to a finished artwork. These requirements were adjusted to the scope of this project, where the goal was to create a functional prototype. Robertson and Robertson (2006) divide requirements into two types: functional and nonfunctional. They also include constraints. Below are the requirements that were set for ARTree.

4.1.2.1 Functional requirements

"A functional requirement is an action that the product must take if it is to be useful to its users" (Robertson and Robertson, 2006: 9). The functional requirements for ARTree was set to be:

- ARTree should have branches that are movable
- The markers should be able to be attached to and moved on ARTree
- 3D objects should be visible on ARTree using augmented reality technology
- One should be able to see these objects from different angles

The reason for requiring movable branches and markers that could both be removed and attached is that it enhances the user's options for interacting with the art. If the markers were permanently attached to the tree, the art would be static, and made solely by an artist. With movable markers the art becomes dynamic, and allows the users to participate in the creation of the artwork. The movable branches lets users adjust the branches to better attach and arrange markers the way that they want them. The decision to create 3D objects and not e.g. 2D images for the tree was to encourage the users to walk around the tree, looking at the tree and the objects from different angles, as a way of enhancing the user experience. To see the objects from different angles, the markers needed to stand out on the tree, which lead to the decision of creating the tree with just branches, and no leaves, as the leaves could easily cover the markers from certain angles.

4.1.2.2 Nonfunctional requirements

"Nonfunctional requirements are properties, or qualities, that the product must have. In some cases, nonfunctional requirements – these describe such properties as look and feel, usability, security, and legal restrictions – are critical to the product's success" (Robertson and Robertson, 2006: 10). For ARTree, the nonfunctional requirements were:

- ARTree should be made in a material that is flexible
- ARTree should be big enough for users to interact with it, but small enough to be easily mobile
- Four 3D objects should be made, each one representing one of the four seasons
- The 3D objects should be visible through a handheld device

ARTree needed to be big enough to hold multiple markers, the main purpose being that it was to be used during the evaluations. As it was decided to augment the four seasons, only one 3D object was made per season so that the user could easier connect each of the objects to a specific season. Handheld devices were chosen because they can enhance interaction with their ability to be mobile and therefore letting the users walk around holding them and experiencing ARTree from different angles.

4.1.2.3 Constraints

"Constraints are global requirements. They can be constraints on the project itself or restrictions on the eventual design of the product" (Robertson and Robertson, 2006: 10). Constraints for ARTree were:

- The project should use existing software to create and visualize the 3D objects
- ARTree should be finished during spring 2010

As this was never intended to be a project within system development, and as software for both creating and visualizing 3D objects are currently available, a prerequisite was that some time needed to be spent reviewing and learning how to use different software to find the best solutions for this project.

4.2 Development tools

As mentioned above, one of the requirements for developing ARTree was that existing software should be used for creating and visualizing 3D objects. As AR has become more commercially available in these last years, software and applications for usage within AR has also become more available. In the beginning phases of this project, some time were spent searching for the right tools for this project[4].

4.2.1 Augmented reality software

The original idea from the brainstorming sessions was to use mobile phones to interact with the prototype. However, doing so by using existing software proved to be difficult. A few free augmented reality browsers are available today, such as Layar[5] and Wikitude[6]. However, these two both work in the way that they use GPS to find points of interest, and visualizes AR objects that are connected to these locations. As ARTree as a prototype is rather small of size, software that uses GPS would be of little help here, as only one point of interest could be connected to the prototype. Therefore it was decided to focus on using software that takes use of markers for visualizing AR objects. At this point it was also decided to use a handheld screen instead of a mobile phone when evaluating the prototype, as there were

[4] The review of software for the project was conducted during autumn 2009, and it is possible that new and better solutions have been developed since then

[5] Layar: http://www.layar.com/

[6] Wikitude: http://www.wikitude.org/

more options when it came to augmented reality software for regular computers than for mobile phones.

Different kinds of software that uses markers were tried out, some of the most promising ones were ARToolkit[7] from ARToolworks, and FLARToolkit[8]. The latter seemed to still be in the development phase, and required some additional programming for adding more than one object, and therefore it did not sufficiently fulfill the needs of ARTree. ARToolkit is well- known and widely used, but is a rather complex system, and was therefore also discarded.

BuildAR[9] is a free software application for creating marker-based augmented reality scenes developed by the Human Interface Technology Laboratory New Zealand (HIT Lab NZ)[10], a human-computer research center in connection to the University of Canterbury in New Zealand. BuildAR shows a live view of an AR scene when connected to a webcam and has features for creating AR markers, as well as adding, scaling and positioning 3D objects. Its graphical user interface is minimalistic and easy to remember, providing only the most necessary features. The interface does have its limitations, such as lack of using keyboard shortcuts to e.g. save or open a file, as well as not being intuitive from a user's perspective, requiring them to read a tutorial before understanding how to use the interface. There are also severe limitations when it comes to which file formats that are supported for the 3D objects, and it is obvious that the application is still being developed. However, for this project, the benefits from using BuildAR outweigh these limitations, and it was decided to use BuildAR for creating the AR scene for ARTre. During the final stages of developing the prototype, HIT Lab NZ released BuildAR Pro which offers more

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[7] ARToolkit: http://www.artoolworks.com/

[8] FLARToolkit: http://saqoosha.net/en/flartoolkit/

[9] BuildAR: http://www.buildar.co.nz/

[10] HIT Lab NZ: http://www.hitlabnz.org/wiki/Home

features, such as the ability to display video and text as well as 3D objects, and it also allows for a wider range of file formats for the 3D objects. However, BuildAR Pro had some initial technical problems, and it was chosen to continue to use the free version of BuildAR.

4.2.2 3D modeling software

As it was decided to create 3D objects for ARTree, it was necessary to spend some time learning how to work with 3D modeling software, and how to create the objects needed for the project. Again, different software was considered. Blender[11], a free open source 3D graphics application seemed like a good choice. However, its user interface provided a frustrating user experience, e.g in that it requires the user to manually write the file path for where to save the file. In addition to having a good user interface, it was crucial that the software chosen would work well together with BuildAR, which turned out to be more challenging than expected. While Autodesk Maya[12] was considered to have a more developed and far better user interface than Blender, it would not let animations be exported in the necessary file formats.

As mentioned previously, BuildAR accepts only a few file formats for the 3D models. The preferred formats are IVE or OSG, both are Open Scene Graph[13], an open source graphics toolkit written in Standard C++ and OpenGL. BuildAR also supports 3DS (3D Studio file), LWO (Lightwave), OBJ (Wavefront Object), STL (Stereolithography) and FLT (OpenFlight), but these file formats have with varying quality when used with BuildAR. Two of the 3D models for ARTree are animations, and these were made using functions for particle systems, which can only be exported to an OSG file out of the file formats supported by BuildAR. Another product from Autodesk, Autodesk 3ds Max[14] ended up being the final choice for 3D software, together with OSGExp[15],

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[11] Blender: http://www.blender.org/

[12] Autodesk Maya: http://usa.autodesk.com/adsk/servlet/pc/index?siteID=123112&id=13577897

[13] Open Scene Graph: http://www.openscenegraph.org/

[14] Autodesk 3ds Max: http://usa.autodesk.com/adsk/servlet/pc/index?id=13567410&siteID=123112

an open source exporter that exports animations and models from 3ds Max to an editable OSG file. Some adjustments needed to be edited in the OSG files so that the animations would be visualized as was intended.

4.3 Prototyping

The second and third activities in the interaction design process is according to Sharp, Rogers and Preece (2007) to develop alternative designs based on the given requirements, and to create interactive versions of these designs. These activities have been executed in form of prototyping. There are two kinds of prototypes, low-fidelity prototypes and high-fidelity prototypes. The former are often paper-based, and does not resemble the final product, but are good and cheap in the way that they can be easily altered. The latter kind resemble the final product far more, and are made using materials that the final product could also be made of (Sharp, Rogers and Preece, 2007). Both kinds have been used in the design process for ARTree. While the early designs for ARTree were low-fidelity prototypes in form of sketches on paper, the final prototype is a fully functioning high-fidelity prototype made from materials that are also realistic to be used in creating the final product.

Dünser et al. (2007) suggest using well-known design principles also when designing an AR interface as a way to avoid the most crucial usability problems. They claim that certain existing design guidelines can be applied to any kind of human-computer interface, as long as they are interpreted in the context for which they are to be used. Some of the design principles suggested by Dünser et al. have been considered while designing ARTree, as described further below.

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[15] OSGExp: http://sourceforge.net/apps/mediawiki/osgmaxexp/

4.3.1 The tree

The first thing created was the tree prototype, as this should serve as a canvas for the 3D objects and it was necessary to know what size and shape these should be to fit the tree. There were several different ideas on how to approach the task of making the prototype for the tree. Using a tiny real tree was not an option, as this could be misunderstood as simply a decorating object in that it was too realistic and did not resemble any kind of art. Also, from the requirements, it was clear that the tree had to be made in a material that could be manipulated by the user, and early on it was decided to take use of steel wire thin enough to be bent by users. The initial thought was to make the tree look more like a tree – by covering it in pieces of wood. However, there was a concern that this could lead to it not being visible enough for the user that it is actually possible to move the trees branches. Also, this being a prototype of an artwork, artistic freedom opened up for the possibility for choosing non-realistic material to make the tree.

After sketching some low-fidelity prototypes on paper, physical high-fidelity prototypes were created. The first prototype was made in a small scale to see if it was possible to make the kind of tree imagined, and to become familiar with the steel wire. The first prototype was an 18cm tree made solely out of steel wire. Dünser et al. (2007) mentions the design principle affordance as being transferrable to AR systems. In this case, the tree branches could have affordance in the way that it was clear that the thin steel wire could be bent in any direction. It was then decided that this method would work well for the final prototype as well, and that it would not be necessary to cover the steel wire with anything. The same kind of approach was used to make a bigger tree for use in the evaluation. The final prototype is 51cm, which if put on a table was big enough for users to interact with during the evaluation.

Figure 3: The tree

4.3.2 3D objects

The tree was to be augmented to somehow show each of the four seasons, and to give the users the opportunity to interact with these augmentations it was decided to create a 3D object for each season. Dünser et al. (2007) mentions the design principle of reducing cognitive overhead, so that the user can focus on the actual task. Cognitive overhead is described by Rizzo et al. (2005: 1) as "the extra non-automatic cognitive effort required to interact/navigate". In order that understanding the 3D objects would not become a distraction for the users during the evaluation, it was necessary to create objects that represented one specific season. Of course, different users may associate different weather or attributes with the seasons, because of differences in geography, cultural background or personal preferences. However, the aim was to create objects that most people would associate with the seasons, and these four 3D objects were made in connection to the four seasons (see figure 4):

- Spring: pink flower buds
- Summer: green leaves
- Autumn: rain
- Winter: snow

Creating the 3D objects was challenging technically. The objects for autumn and winter, i.e. rain and snow, were animations made using particle systems in 3ds Max. When exporting the animations, only some of their features remained, and it was necessary to edit the OSG code in terms of size, color, amount and so on to make the animations look satisfyingly like rain and snow. For spring and summer, image files for flower buds and leaves were made using Photoshop[16], and were then multiplied a vast amount of times and arranged into 3D objects in 3ds Max.

[16] Photoshop: http://www.photoshop.com/

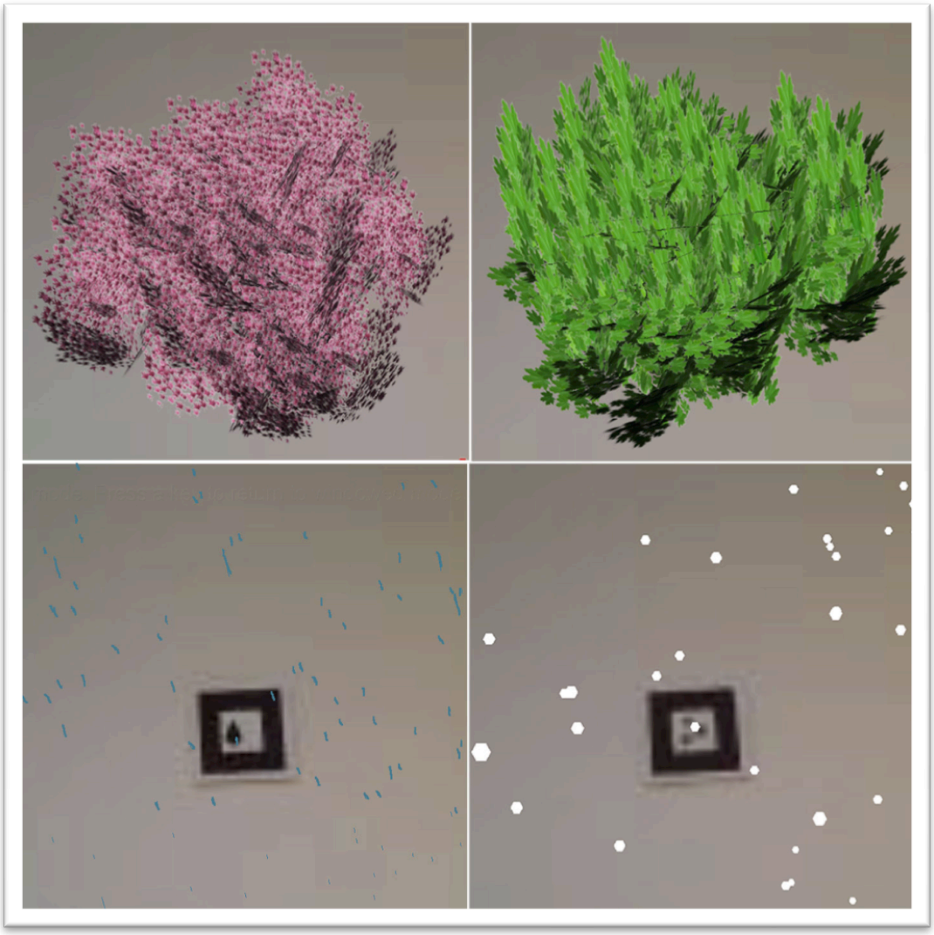

Figure 4: 3D Objects: spring, summer, autumn and winter

4.3.3 Markers

BuildAR needs one marker for each augmented reality object, and these need to be easily separated from one another. They need to have a black square with a white edge, be made in contrast colors, be big enough to be identified at a certain distance through the webcam, and they need to be asymmetric, so that it is possible to tell which way is up. Creating the markers was also an iterative process, and many alternative markers were made. A selection of these are pictured in Figure 5. Still considering the design principle of trying to reduce the user's cognitive overhead, as well as the design principle of consistency, it was decided that each marker should clearly represent one season. Two sets of markers were made at first, one with text and one with icons. The set of markers with each season written on them (see line one in Figure 5) were excluded due to a combination of the text being hard for the webcam to pick up from a distance, and that black and white markers with only text seemed somewhat plain for an art project, offering little to enhance the user experience. The set of markers with icons was therefore chosen, and each marker was given an icon that represented the season it was to be connected to (see line two in Figure 5).

While testing the markers placed on the tree with BuildAR and a webcam, it became clear that it was not possible to tell some of the markers apart from a distance, no matter what size they were. The requirement was that one should be able to stand far enough from ARTree so that the whole tree was visible on the screen. The icons for spring and autumn were replaced with new ones that did not resemble the shape of the summer icon as much, and the symmetric icon for winter were replaced with an asymmetrical one.

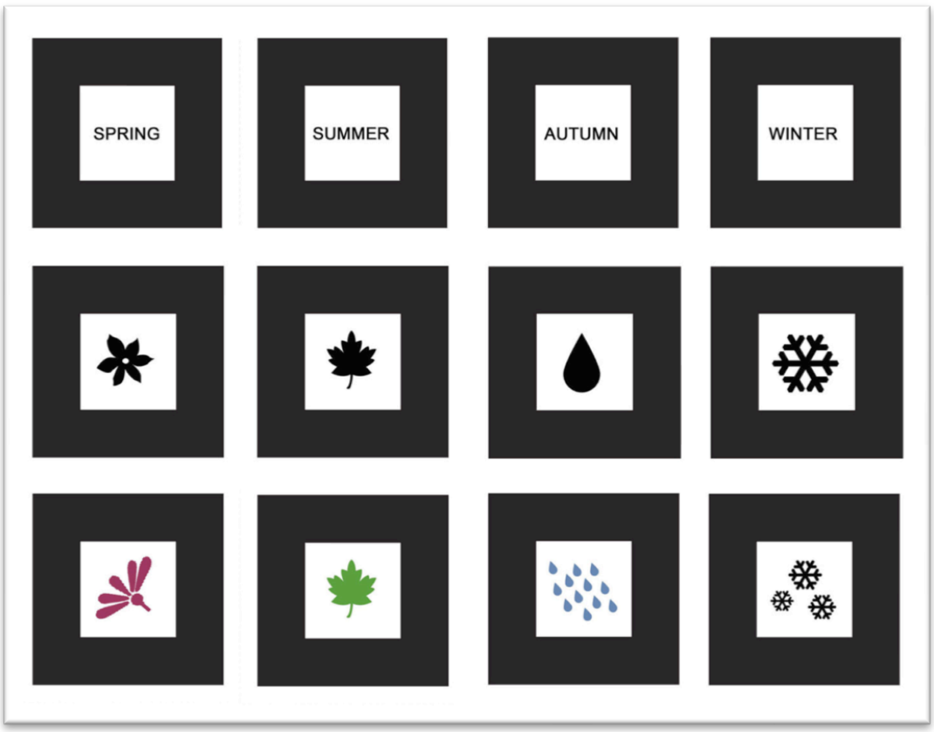

Figure 5: A selection of the markers made for ARTree

As there was still trouble telling the icons apart, colored versions of the icons were made (see line three in Figure 5). At this point it became clear that the problem was not so much the icons, but the size of the markers. As ARTree is a prototype of an artwork and aesthetics should be considered, it was requested that the markers should not be too dominating, and be made as small as possible, even though the markers for spring and summer were fully covered by their 3D objects. But because of these technical issues, compromises had to be made, and the markers ended up being 6,5 x 6,5 cm, which may seem out of proportion on the tree. Figure 6 shows the final markers. The marker for autumn had to be adjusted at the last minute as there at times still was trouble telling it apart from the summer marker, and the solution was to make it asymmetrical within the black frame. Again, considering the design principle of consistency, the markers were all made in black and white for a clean look.

Figure 6: The final set of markers

As the prototype is made from steel wire, it was easy to find a solution for how to easily attach and remove the markers from the tree. After printing out the markers in the right size, these were attached to pieces of cardboard, which was then attached to self-adhesive magnets that could be placed on the steel wire branches. A consequence of the markers having to be larger than what was anticipated was that they also became heavier, which could impact the use of markers as tangible paper-based interaction, as they were not as easy to attach to the tree.

4.4 Experiences with developing a prototype of AR art

The first research question for this study was:

- How can augmented reality be used in art?

The related research activity for finding answers to this was to develop a prototype of AR art. This chapter describes the developing of ARTree, and the answers to the research question lies in the experiences made during this process. The feasibility of AR art is proven through a functioning ARTree prototype, and further so through the evaluations.

In chapter 2, some criteria for AR art were set, and through the design process it was a goal to create a prototype that fulfilled all of these criteria. ARTree consists of a tree, which may be called a physical work of art, in addition to virtual augmentations of this tree. These augmentations are also clearly related to the tree itself, as it is natural for leaves, flower buds, rain and snow in relation to a tree. The users have to pick up and attach markers on the tree to interact with it, and through the selection of markers that are presented to the user, he or she can create their own versions of the artwork. Through all of these features, ARTree fulfills the criteria for AR art.

4.5 Summary of the chapter

In this chapter, the framework for the design process was introduced, the requirements for ARTree were set through brainstorming sessions, and the chosen software for both augmented reality and 3D modeling was presented. The development process of both the tree, the 3D objects and the markers were described. The next chapter describes how the evaluation sessions were planned and conducted, and how the evaluation methods were followed. Findings from the evaluations are presented.

5 Evaluation

This chapter lays out the design for conducting the evaluations as well as explains how the chosen methods for evaluation and data gathering were followed. Experiences with doing a pilot study are summarized, and findings from the main evaluations are presented and analyzed. ARTree is discussed in the light of relevant literature.

The third design-science research guideline from Hevner et al. (2004) says that the design artifact must be evaluated in terms of its utility, quality and efficacy. Evaluating a prototype's user experience is also the fourth and last activity in the interaction design process (Sharp, Rogers and Preece, 2007). The main goals of the evaluation were to answer the research questions about how users interact with AR art, and how users experience AR art. In addition, evaluating the prototype is important for further work with ARTree.

5.1 Evaluation design

Before the pilot and evaluation sessions were conducted, certain choices had to be made as for how to use the think aloud technique, how and what kind of data should be gathered, and how the evaluation sessions themselves should be conducted, including the technical setup for ARTree. The process of conducting both the pilot study and the main evaluations is documented here, while changes made from experiences from the pilot study are mentioned in section 5.2.

5.1.1 Think aloud

The evaluation sessions followed Boren and Ramey's (2000) method for the think aloud technique, through setting the stage by making sure the test users knew that the prototype was being tested, and not them, and that the test user was the main speaker, and the facilitators the listeners. Acknowledgment of the test user's thoughts was mainly given through natural speech, by saying "mm" and "OK". Additional interaction was only required during the pilot study, where a cable needed to be reattached. Asking the test users for additional information were necessary on several occasions, mainly by asking them to clarify what they were saying, as well as explain *why* they were doing what they were doing or thinking what they said they were thinking. Also following Boren and Ramey's (2000) proposal, a debriefing was conducted at the end of each session, as the test users had questions about the technology and area of use, and we had further questions about how they experienced interacting with ARTree.

5.1.2 Test users

The number of users for the evaluation was decided on the basis of Jacob Nielsen's (1994 cited in Nielsen, Clemmensen and Yssing 2002) suggestion that five users is sufficient for conducting a think aloud test. The goal was to have test users from different backgrounds, and it was also requested that the test users had as little previous experience with AR and digital or interactive art as possible, as it would be interesting to study how users with no previous experience with this kind of technology would interact with AR art. In addition, the artist was also involved in the evaluation, both to give insight as to how the artist behind the artwork interacts with the artwork, and to discover how she reacted to the finished prototype compared to the idea we started with at the brainstorming sessions.

Experiences from the pilot study (see section 5.2) lead to the decision to do one of the evaluation sessions with two users together, letting them "think loud" to each other, to see if they more frequently articulated their thoughts and actions, and also to study the interaction as a collaboration between two people. Users 3 and 4, who did not know each other from before, were asked to do the evaluation together. The five test users were both men and women from the age of 23, and they participated in these four evaluation sessions (see also appendix C):

1. User 1: a 27 year old man with no knowledge about or experience with both AR and digital or interactive arts
2. User 2: a 27 year old woman with no knowledge or experience with AR, but who had experienced digital or interactive art before
3. User 3: a 23 year old man who had heard of AR, but never experienced either AR or digital or interactive art
   User 4: a 24 year old man who had also heard of AR, but never experienced it, or digital or interactive art
4. User 5: the artist Jannicke Olsen, who did not state her age, but have agreed to be identified by name in this study. She had of course heard of AR before, but never experienced it until during the evaluation session. She did however have previous experience with digital or interactive art.

5.1.3 Conducting the evaluations

The users were first greeted and introduced to the others in the room, then handed the consent form and questionnaire, asked to read them and fill them out. They were thereafter explained how to use the think aloud technique, they were asked to express and explain their thoughts, actions and so on. They were also reminded that the session was being video taped, that they could do nothing wrong, and that it was the artifact being evaluated, and not them. After checking their answers in the questionnaire to see if they had any experience with AR or digital arts to know if they should be studied as novices or as experts, they were told that what they needed were placed on the table in front of them, and that they could do whatever they wished with what was there.

5.1.4 Setup

The evaluations were conducted in a room at the department of information science and media studies. The room was chosen because of good lighting conditions, as well as its location. It is located so that people seldom walk by, and therefore there were small chances of other people interrupting the evaluation sessions. ARTree was placed on a low table in the middle of an open space in the room, allowing enough space for the test users to walk around the table without bumping into any obstacles. The handheld screen, which had a webcam provisionally attached to the back by the use of masking tape, and the bowl containing the three markers that were not already placed on ARTree were placed on the table next to the tree (see Figure 7).

A change in the setup was made after the first evaluation session, where the handheld screen was placed in the upright position on the table. It took the test user some time to understand that he needed to pick up the screen to see the augmented reality objects placed on the tree, and all he could see through the screen before picking it up was the tree trunk. For the remaining evaluation sessions, the screen laid flat on the table instead of being placed in the upright position. The evaluation sessions revealed findings about the setup, these are further described in section 5.3.5. The screen was attached to a computer through several wires, and video was recorded from the handheld screen.

In the room together with the test user(s) were myself, in the role of the main facilitator, and Tor Gjøsæter, who recorded video of the test users interacting with ARTree, as well as sometimes also participating as a listener and dialogue partner for the test users. As the sessions were videotaped, notes were not taken during the evaluation sessions, which allowed for the focus to be entirely on taking on the role of the listener for the think aloud technique.

Figure 7: Setup for the main evaluations

5.1.5 Consent form

The consent form (see Appendix A) gave the users information about the project, telling them it was a project researching user experience of AR in art, and that the purpose was to get an understanding of how users interact with augmented reality art. They were informed that the data collected from the evaluations would be used in this thesis as well as in an article, that the sessions were being video taped, and that screen shots and quotes could be used, but that they would not be identified by name. Lastly, they were explained the think aloud technique and asked to use it during the evaluation. They were also told that the evaluation would last approximately 15 minutes and that they could withdraw from the evaluation at any time.

5.1.6 Questionnaire

The questionnaire (see appendices B and C) was handed out before the evaluation was conducted, to be aware of the test user's background while observing them interacting with ARTree. The purpose of this was to know if they had any knowledge about or experience with AR, which would tell us for example if they were aware of that one would have to hold the camera straight in front of the marker to make the AR object appear. They were also asked about their experiences with interactive art, and if they had previous experience with interactive art to know if they were familiar with this kind of interaction. The questionnaire had a field for evaluator number, filled out before the user entered the room, as a way of connecting the questionnaire to the video recordings of that session. The users were asked to fill out their age as well as answer questions about their previous knowledge about and experience with AR, as well as their experience with digital or interactive art. This was done using yes/no boxes, as well as allowing them to elaborate if they answered yes to any of the questions, also including some qualitative questions in the questionnaire. The reason for not collecting more quantitative data through the questionnaire was that the results could not be generalized due to the low number of test users.

5.2 Pilot study

According to van Teijlingen and Hundley (2001), a pilot study can be either a feasibility study that is a trial run of the evaluation, or a way of trying out a research instrument. Both quantitative and qualitative methods can be used for pilot studies. Pilot studies can highlight possible issues concerning how test users respond to questions in questionnaires, identify practical issues such as time frames, deciding how many people need to be involved, and so on, in addition to being a way of collecting preliminary data and be a way for the researcher to practice the methods used. While doing a pilot study, it is important to consider how to deal with contamination, i.e. if findings from the pilot study should be included in the results for the main evaluation, or if the participants from the pilot study should also take part in the main evaluation. Van Teijlingen and Hundley (2001) also stress the fact that academic papers fail to document the process and outcome of a pilot study, and simply state that changes was made after conducting a pilot study, offering little input to others doing similar research.

Even though qualitative evaluations are often progressive, in the way that the researcher can improve the methods used from experiences during the first few rounds of evaluation, there are also benefits from doing pilot studies for evaluations relying on qualitative methods (van Teijlingen and Hundley, 2001). A pilot study for the evaluation of ARTree was conducted in form of a feasibility study with a desire to discover possible issues concerning:

- Technical issues: interacting with the handheld screen, the markers and the tree
- Consent form and questionnaire: making sure the information in the consent form as well as the questions in the questionnaire was easy to understand
- Think aloud: get familiar with using the technique, and see if the test user understood how to "think aloud"

The pilot study was conducted with one test user, and was very useful for the main evaluations. The results from the pilot study were not included in the main results, but the outcome of the study was that several changes were made for the main evaluations. The test user for the pilot study was a 25 year old man who had previous knowledge, but not experience with AR, and who did have previous experience with digital or interactive arts.

5.2.1 Outcome from the pilot study

For the pilot study, the questionnaires only contained yes or no answers to the questions. Because there are different kinds of both AR and digital or interactive art, the questionnaires were modified to include the possibility to elaborate on each of the questions. The pilot user mentioned that he found it somewhat hard to understand how to "think aloud" only by reading about it in the consent form, and so the test users for the main evaluations were explained how to "think aloud" as well as reading about it in the consent form. For the pilot study, all four markers were placed on the tree, and it appeared as though the user did not understand that he was allowed to move them. For the main evaluations, only one marker was placed on the tree, to give the users a hint about what they could do with the markers, and the remaining three markers were placed in a bowl next to the tree.

The pilot user talked about the AR object for spring as being a "grey cloud", which highlighted the fact that people who are colorblind can experience the prototype differently than those who are not, and the test users for the main evaluations were asked if they were colorblind before starting. Reviewing the video recordings of the pilot study, it became clear that some leading questions were asked, knowing this helped to prevent this in the main evaluations. The pilot user was somewhat reluctant to elaborate on what he was thinking and doing, unless asked to do so, which resulted in the decision to do one of the main evaluations with two test users together, to see if they could better communicate their actions and thoughts as a group. The pilot study also indicated how long each evaluation session would take, which was approximately 15 minutes.

5.3 Findings

Patterns in the evaluation sessions were found, and findings were then divided into different categories depending on what the findings were related to: interacting with AR art, user experience with ARTree, markers, objects, technical setup as well as outcome from the debriefing.

5.3.1 Interacting with AR art

The second research question for this study was:

- How does users interact with augmented reality art?

Answering this question was the focus for the evaluations. How the users interacted with ARTree differed somewhat for each evaluation session. In session 1, where the screen was placed upright on the table, the test user started by placing all the markers on the tree, not just on the branches, but also on the tree trunk. He first noticed the winter object, which he had coincidentally placed in the camera's view, and this is how he discovered the objects. He then removed the winter marker, and noticed the object disappear from the screen. He then put it back, and picked up the screen to hold it in front of the other objects, now that he understood how the technology works. The first test user seemed as though he was trying to solve a task, placing the markers where he thought it was logical to place them, for example the marker for snow was placed on the ground.

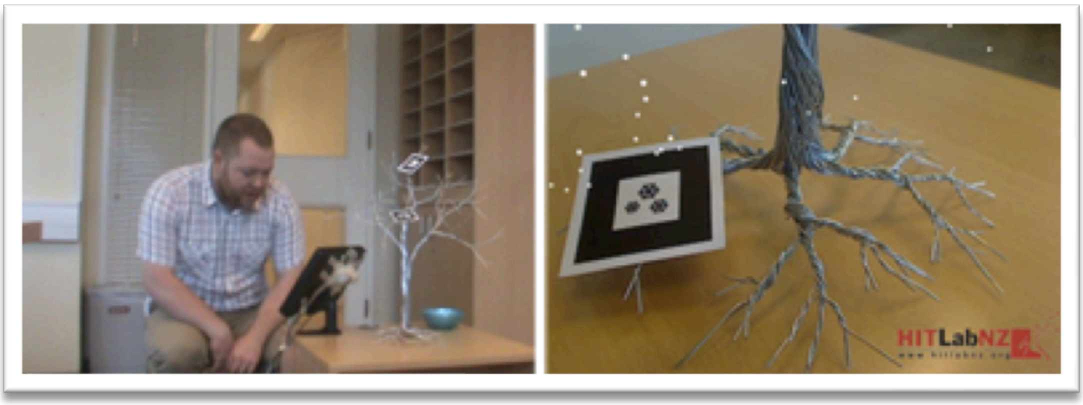

Figure 8: Snow marker placed on the ground

In the second evaluation session, the screen was laid on the table, and the first thing the test user did was to pick it up and hold it in front of the marker on the tree, as if she knew intuitively that that was what she was supposed to do. She then placed a new marker on the tree and looked at it through the screen, only to remove it and replace it with a new marker, apparently curious to see which object was connected to that marker. She placed all the markers on the tree, and said that she was fascinated and that she wanted to see all the objects on the screen at once, and was surprised to find that she could do so. She also tried to walk backwards, seeing how far away she could go while still seeing all of the objects. While doing this, she said that she preferred to see the tree from a distance, as there was a wholeness to seeing all the objects at once, rather than standing close and only seeing one object at a time.

Figure 9: Test user two seeing all four objects at once

The test users in session 3 worked well together while interacting with ARTree, with one of them holding the screen and the other attaching and rearranging the markers, and then changing roles after a while. It was also interesting to see how they communicated with each other to understand what they were doing. Instead of thinking out loud, one of the users asked the other e.g. “what is that supposed to be?”. One of the users picked up a marker, turned it around to see the magnet on its backside, and placed in on the tree, while the other user was holding the screen. The first user then went up to the other to look at the screen together with him. They also noticed through exploration that the markers needed to face the camera for the object to appear on the screen, and that it is not possible to see the object if branches are blocking the markers from the camera.

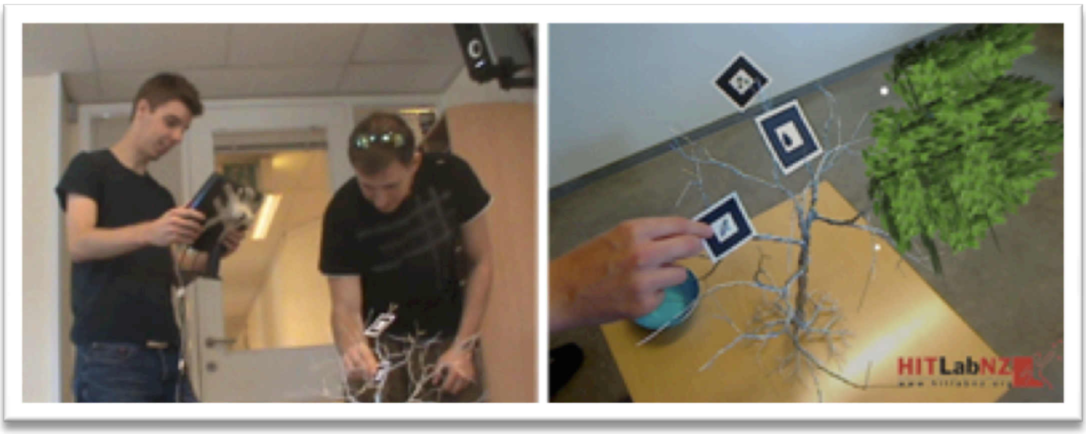

Figure 10: Test users exploring ARTree together

The artist, who was the test user in session 4, interacted a little differently with ARTree than the other users did. This was most likely because she had expectations to what was going to happen, and that she to some degree knew how AR and ARTree works before the evaluation. She picked up the screen right away, and took her time looking at the object already placed on the tree from all angles, from close by so that the object disappeared, as well as from a distance. From that she learned how the technology works, and how close or far away she could go and still see the objects. She also held the screen over the bowl that contained the remaining markers before picking them up and placing them on the tree, exploring the objects apart from the physical art. She then placed markers on the tree's roots and trunk, while she started telling a story about the objects, and wondering if the objects were giving her hints on what to do. She walked around the tree while still looking through the screen, to see if anything exciting would happen.

Figure 11: The artist exploring the snow object apart from the tree

The tree was created in steel wire so that it would be possible for the users to also move the branches on the tree, and not only the markers. However, none of the test users did this during the evaluations. It is possible that this is because they thought of the tree as regular static art, as opposed to interactive art, and as we are used to art being off limits when it comes to touching and adjusting, they therefore became a passive audience. Another common denominator for all the sessions is that it seemed like all of the test users thought it was a task, solved by placing all the markers on the tree at once and seeing all the objects through the screen at once, and they all seemed content when they had achieved this. Even though all users explored the basic possibilities of ARTree, there is still a barrier for how they interact. All users placed the markers on or in close proximity to the tree, and did not explore other possibilities for where to place them. They also did not e.g. turn the handheld screen in other positions, or move the tree. All of these actions would have been possible, and could have given the users a different user experience with ARTree.

5.3.2 User experience with ARTree

As the test users did not verbalize all of their thoughts through using the think aloud technique, it was difficult to answer the third research question:

- How does users experience augmented reality?

However, some expressions of the user experience of ARTree were mentioned during the evaluation sessions, and more during the debriefing. User one said that he found ARTree exciting and fun, and user two said that it was fun and fascinating. User two also said that it was fun to move things, that you get to see something new every time, and that you get a new experience every time you look at the tree. Users three and four said that they would prefer looking at or interacting with ARTree to just the tree itself, and that it was nice being able to change the art. They also said that it was exciting. In the fourth evaluation session, the artist started telling a story built around which impressions she got from ARTree, and she said that she was pleased with the outcome of the prototype, claiming it was exactly like she had expected.

The common denominators here are that ARTree gives a positive user experience, and that users have fun while interacting with it. Also, like mentioned above, users experience that the meaning of ARTree is to solve the task of placing all the markers on the tree at once, which some people can find exciting. It also seems as though the users find it pleasing that their actions have an influence on the art, and that they are comfortable with changing the artwork, unlike what they would be when it comes to static art in e.g. an art gallery.

5.3.3 Markers

Using markers as a way of interacting with an artwork was new to all of the test users, and although it may be an unnatural way of interacting for most people, the users learned quickly how the markers worked. Several of the test users looked at the back of the first marker they picked up and noticed the magnet on the backside. A clue had been given to them about the possibility to attach the markers to the tree through introducing them to the tree with a marker already attached. All of the test users had some difficulty attaching the markers to the tree, this was most likely because it is hard to attach anything on the thin branches, and that the markers were a bit too heavy for them. Markers falling down as the test users touched the tree to attach new markers was also an issue, which was most likely due to the size of the markers. It also happened on occasion that test users placed a marker so that a branch was in front of it, disabling the computer to recognize the marker so that no object appeared, this was also highlighted by user number two during the evaluation.

Another issue concerning the markers was some confusion about the icons on the markers. The first test user looked at all of the markers in his hands before looking at them through the handheld screen, and he said that they reminded him of the four elements. He later said that the summer marker with a leaf icon made him think of Canada, and that he found the spring marker with a flower hard to understand. The artist also had some issues with these same two markers, saying that they were somewhat unclear. However, test user number two had no problems understanding that the markers represented the seasons, highlighting the fact that different users will understand the markers in different ways. The artist mentioned that the markers did not come together with the tree aesthetically, which is somewhat due to the unexpected size of the markers. On a larger tree and with creating the markers a little differently, possibly shaped like leaves, they could be better integrated with the tree.

5.3.4 Objects

The test users mostly understood what the objects were, but there were some differences when it came to how the users experienced the objects. User one is colorblind, and experienced the objects somewhat differently than the rest, as when he described the pink flower buds object for spring as “green in some places, but to me it looks mostly grey”. User number two understood the spring object with flower buds as “some kind of flower”. She also questioned the depth of the snow, indicating that the size of the snowflakes and the 3D effect was not satisfying. The users in session three understood the objects as “different weather and seasons”. From this we understand that some of the objects could have been made clearer. However, this being a work of art, it is now crucial that the users understand every piece of it as long as they can enjoy it.

5.3.5 Technical setup

As only a prototype was tested during the evaluations, some of the technical solutions were somewhat provisional, and some issues were highlighted. The table where ARTree, the handheld screen and the bowl containing the markers was placed so that is was possible for the test users to walk around it. However, the only user who took the opportunity to walk around the table and see ARTree from all angles was the artist. All of the other users only walked a few steps in each direction, staying at the same side of the table at all times. On the question of how they experienced walking around with the handheld screen and interacting with ARTree, all of the users answered that the cables that were attached to the screen made it somewhat unmanageable to walk around too much while holding the screen. A solution to this could be to use a wireless screen, or to create an interface for mobile phones, as discussed further in chapter 6.

The test users gave some feedback about how some of the AR objects seemed to move or jump in BuildAR, and some of the users wondered if this meant something, not knowing it was due to a technical error. Another issue with BuildAR was that an axis sometimes appeared together with the AR object, which the users were somewhat distracted by, as it took the focus away from the object itself. BuildAR was at the time of the evaluations in an early version, and these problems have most likely been corrected.

One thing about the technical setup that surprisingly did not cause any confusion for the users was the experience of looking through the handheld screen as if it was a window. The screen had a webcam attached to the back, but few of the users looked at the back of the screen, simply accepting the fact that they could see “through” the screen, not questioning how. This shows that the technology of AR can be easily accepted for regular users without any previous knowledge to AR.

5.3.6 Outcome from the debriefing

In all the evaluation sessions, the evaluations went naturally on to a debriefing conversation as the user felt like he or she had explored ARTree sufficiently. Both the users and the facilitators asked questions during the debriefing. The test users had questions about ARTree, and we had questions about the user experience with ARTree, and augmented reality art. We specifically asked them if they thought they would interact with ARTree as a finished artwork, as opposed to the prototype they had just seen.

User one was interested in knowing what the area of use was for ARTree. When asked if he would have used it if he had seen ARTree in a big scale placed in a public place, he answered that he would probably have let it be, since the technology was new to him. On the question of how he thought about interacting with the art instead of just looking at it, he said that it brought an exciting element, and that to him, it was mostly fun. He also said that art is permanent, and when it is changed, it can no longer be called art. He did however propose the option to freeze the image and make it possible to take a screenshot of ARTree the way that he arranged it, and he said that in that way it could still be called art. He also said that ARTree has some pedagogical features, and it could be used to give pupils an understanding of what a computer can do, and let them explore by rearranging the markers the way that they want to.

User two said that she probably would interact with a big scale ARTree, as she is curious of nature. She also said that it was fun to move the objects, and that one gets a new experience every time. User 3 in session 3 said that he would definitely interact with ARTree had he seen it in a public place, while user 4 in the same evaluation session was more hesitant. He did however say that he would like to have a similar artwork in his living room. They both agreed that ARTree can be called art, but they specified that it is art that the users can assemble themselves.

The debriefing part with the artist naturally took longer time than with the rest of the test users, as we discussed how ARTree had turned out in comparison to the ideas we had during the brainstorming sessions. She said that ARTree was like we had described during the brainstorming sessions, and she said that the collaboration had worked well. She highlighted the fact that we had been attentive, and good at explaining to her which possibilities and limitations there were when creating augmented reality art. This shows the importance of including both technologists, preferably some with knowledge about human-computer interaction, and an artist in such a project. The debriefing with the test users gave us some answers about the user experience with ARTree, and showed that most of the users (3 out of 5) mean that they would interact with a finished ARTree.

5.4 Discussion

The evaluation revealed how the users interacted with ARTree, and showed that the interaction cohered with the definition of interactivity introduced in chapter 2. Jens F. Jensen (1998) said that interaction can be said to be "a measure of a media's potential ability to let the user exert an influence on the content and/or of the mediated communication" (Jensen, 1998: 201). When it comes to ARTree, this definition fits especially well when it comes to users exerting an influence. For ARTree, the users cannot influence the content, however, as all parts of ARTree are laid out for them, but they can influence the way the parts – or the content – is put together.

Rafaeli's (1988) elaborated definition of full interactivity also coheres with the interaction between the users and ARTree. This especially shows after the user has placed multiple markers on the tree, and can see the results of his or her resent interaction combined with the presence of results of earlier interaction. In other words, the appearance of ARTree is a result of the full interaction between the user and ARTree, as the markers and objects placed on the tree one by one, together creates the augmentation.

The finished prototype of ARTree also fits well within Cornock and Edwards' (1973) third category of types of interactive artworks, the dynamic-interactive system. The user can indeed interact with ARTree and change it. Change is an important keyword here, as ARTree has its limitations.

ARTree and its setup provides the users with a limited selection of items that they can arrange in the way that they want, in addition to changing the tree's appearance, which none of the users did. They are able to create their own version of the artwork through interacting with the artwork, but they cannot add new things to the artwork, and they cannot create a whole new artwork of their own. It may be that it would be more accurate to say that the users can *rearrange* the artwork than that they can change it.

Through this study, it has become clear that Edmonds, Turner and Candy's (2004) claim that an artist needs to have knowledge of programming to have artistic control over the artwork is not necessary true. Even though the artist mentioned during the evaluation that the markers and objects did not blend well together with the tree, she did say that the finished prototype was just what she expected. There is little doubt that further collaboration between technologists/usability experts and the artist would have resulted in an improved version of ARTree, both from a technological and an artistic point of view, and that through that kind of team work it is possible for both sides to maintain control over the artwork.

The findings from the evaluations cohered with what Todd Winkler (2000) wrote about interactive art not requiring the user to have any kind of special training or talents in order to interact with it. According to Sharp, Rogers and Preece (2007), learnability is about how easy it is to learn to use a system. Even though all of the users were new to AR, ARTree proved to have high learnability, as they all managed to quickly learn how to interact with ARTree, no special training or talents necessary, only their curiousness and willingness to explore something new. During the evaluations, the users quickly learned how to position the screen so that they could see the 3D objects, and they experimented with how far and how close to the marker they go while still being able to see the objects.

Costanza, Kunz and Fjeld's (2009) describes augmented reality as having more physical elements than virtual elements, which we can also see with ARTree. Although the virtual ones outnumber the physical ones, the tree itself is the most dominant object, and it can be called a work of art even without the virtual augmentations.

The criteria for AR art first described in chapter 2 served as goals for how ARTree should be, and those goals have mostly been met.

- Augmented reality art is the combination of a physical artwork and a virtual augmentation of this artwork
- The virtual augmentation needs to be related to the real art

- The interaction between the user and the artwork should be deliberate
- Through interacting with the AR art, the user should be able to change the artwork so that each user takes part in creating their own version of the artwork

ARTree is indeed a combination of a physical artwork and a virtual augmentation of that artwork, but as the evaluations revealed, the users found it more natural to rearrange the virtual objects than the tree itself. The objects were however highly related to the real art, and the users seemed to think that the virtual objects did augment the tree. In the way ARTree was set up for the evaluations, there was no way for the users to interact with ARTree non-deliberately. If we wanted to give them this opportunity, we could have e.g. placed all of the markers on the tree before the users entered the room, and placed the screen in such a position that they would easily look at it and see the objects without actually interacting. The last criteria was highly fulfilled with the prototype. All of the users took the chance to make their own version of ARTree.

5.5 Summary of the chapter

In this chapter, the design of the evaluation sessions was presented. A pilot study was documented, as well as the four evaluation sessions that were conducted. Findings from these were presented in relevant categories, and then analyzed. ARTree was discussed in relation to relevant literature presented earlier in this thesis. The next chapter will summarize the thesis and reflect on the process of doing this study.

6 Conclusion

This chapter summarizes the thesis and lists the main results of the thesis, gives a reflection on the study and the research methods used, in addition to presenting suggestions for future research both for ARTree and AR art in general.

6.1 Summary of the thesis

This thesis has documented a study where the goal was to explore the use of augmented reality in art, through developing a prototype of augmented reality art, and thereafter evaluate it. The study was built on a review of relevant literature, technology, previous research and methodologies. After brainstorming sessions involving both technologists/usability experts and an artist, the idea of creating ARTree was born. ARTree is an artwork consisting of a physical tree made from steel wire, and four paper markers, each connected to a 3D object, together representing the four seasons as augmentations of the tree.

ARTree was evaluated through a usability test with five users, using the think aloud technique. Findings were that users find it easy to learn how to use AR in art, that they experienced is as though they were solving a task, and that they only rearranged the markers, but not the branches on the tree.

Chapter 1 introduced the three research questions for this study, as well as their related research activities:

1. How can augmented reality be used in art?
   - ⇒ Research activity: Develop a prototype of augmented reality art
2. How do users interact with augmented reality art?
   - ⇒ Research activity: Evaluate the interaction with augmented reality art
3. How do users experience augmented reality art?

⇒ Research activity: Evaluate the user experience of AR art

Research question one was answered through the development of ARTree, and ARTree itself is an example of how augmented reality can be used in art. The development of the prototype had its challenges, mostly due to technical difficulties, but the prototype did to a large degree fulfill the requirements that were set. During the evaluations, the remaining two research questions were answered. Observing the users as they interacted with ARTree gave an example of how users interact with augmented reality art. All users explored the use of ARTree, and quickly learned how to interact with it. The most substantial common denominators were:

- The users acted as though they were solving a task, and that task was to place all of the markers on the tree, and then see all of the belonging objects through the screen at once
- Neither of the users moved the branches on the tree, not understanding that the tree could also be altered, treating it like they would most static art.

Answering the last research question was somewhat more of a challenge, as the users did not verbalize their thoughts as far as what would have been preferable, and that it is generally difficult to map user experience, as it differs so much from user to user. However, through what the users did think out loud during the evaluations, in addition to what they answered in the debriefing, it can be concluded that ARTree gives a positive user experience, and that users find interacting with ARTree fun and fascinating.

6.1.1 Research contribution

The fourth guideline from Hevner et al. (2004) says that design science must provide a research contribution. The main research contribution for this study is the combining of these three research areas: human-computer interaction, augmented reality and interactive arts. As there is little previous research within this area, this thesis could be relevant for others doing similar studies.

The main results of this study are:

1. ARTree itself, serving as an example of what augmented reality art is, and how augmented reality can be used in art
2. The criteria for augmented reality art, which can be used by others to create and evaluate AR art
3. The suggestion that AR art should be a cooperation between technologists, usability experts and artists
4. Finding that AR art is about exploration, both when it comes to creating AR art, and for interacting with AR art

6.2 Reflections on the study

A challenge with doing this study was the limited availability of previous research in the same research area. As augmented reality art is a new research area, it was difficult to find literature specifically relevant for AR art. However, previous research and other relevant literature from the research areas human-computer interaction, augmented reality and interactive arts were important for the study's theoretical foundation.

Guidelines for design science served as guidance for the study and the thesis. However, as the guidelines suggested by Hevner et al. (2004), were developed for use in information systems, they do not always apply in this context, and it is possible that more relevant guidelines could have served a better purpose for the study.

The development process for ARTree was more time consuming than anticipated, due to technical challenges. However, through several iterations, both the tree, the markers, and the objects were created, and ARTree was a fully functional prototype to be used in the evaluations. As some time has passed since the beginning of this study, it is likely that new and better technology exists today for creating handheld augmented reality. Some suggestions on what could have been differently with ARTree are mentioned in section 6.3.

The evaluations mostly gave the necessary answers to the research questions, but the evaluations also revealed that the think aloud technique did not always work well. Most of the test users needed to be asked to elaborate often, and generally did not *think aloud*, but only answered the questions that were asked. It was interesting to see the interaction during the session with two test users, but they did not think aloud either. It is possible that they would have felt more free to do so if they knew each other previously. The artist, however, seemed to naturally think aloud, and it was not necessary to say anything to her until the session went naturally over to the debriefing part. Section 6.3.1 contains more suggestions for evaluation of ARTree.

6.3 Further research

Some suggestions for further research came from the brainstorming sessions with Jannicke Olsen and Tor Gjøsæter, and later during the process. As Olsen had a vast amount of ideas as to what she wanted for a big scale AR artwork, it was only possible to focus on a few of these for this study. Some of the ideas could make interesting contributions within the research area of augmented reality, and others in interactive art.

6.3.1 Further evaluation

Initially, the intent was to compare the interaction with ARTree when the user was looking at it through a wall-mounted monitor versus through a mobile phone. As there at the time was some trouble finding software for mobile phones, it was decided to use a handheld screen instead. AR is becoming more and more commercialized, and one can assume that new software will be developed shortly that could be used for interacting with ARTree through a mobile phone. Evaluating this would be an interesting research contribution because the mobile phone is a personal device that people feel comfortable with, and it is possible that they would feel more free to interact with ARTree through something familiar, instead of having to pick up a new device. This could also open up the possibility of users downloading new markers on their phones and bringing these to ARTree, or to make their own 3D objects and connect these to the artwork. Another way to expand the scope of the evaluations could be to place ARTree in a public place, and observe how and if users interacted with it while not in a lab-like setting where they were told to interact with it.

6.3.2 Further development of ARTree

Some users had trouble understanding what the AR objects were, and improving these, or replacing them with new ones, could contribute to the user experience of ARTree. Adding more objects would also give the users more options, for example did all the test users place all of the markers on the tree during the evaluations. If there were many markers, they would have to choose which ones to integrate with the physical art, and they could create art that was even more individual. As half of the markers were found to be confusing to the users, replacing these with new markers would also be an improvement. Creating a bigger scale ARTree could also prove to have an impact on the interaction and user experience, as the markers would be more to scale and be more integrated with the artwork, the users would be forced to walk around the tree to see all of the markers, and it could be easier to attach the markers if the branches were thicker. Also, as the evaluations showed that the tree did not have affordance when it came to moving the branches, creating the tree in a different material could make this more obvious to the user.

6.3.3 Further research in AR art

As the evaluations revealed, the users found it hard to interact with ARTree by holding the handheld screen, as the attached cables made it heavy and uncomfortable. Using wireless screens for AR art where the users are encouraged to move around the art could therefore be an option, and mobile phones would perhaps be even better, as mentioned above. The evaluations also revealed that the users had some trouble understanding some of the icons on the markers, so studying the use of iconography in AR art could be interesting to see how icons are interpreted and how intuitive they are. This is also related to what the artist mentioned during the evaluation, which was that the markers needed to be better integrated with the art. She suggested creating the markers in different shapes and materials. Exploring different kinds of markers could be relevant, as well as other techniques for tracking.

Improving the technologies behind AR could lead to extended possibilities for user participation. For example, it could be interesting to let users themselves upload objects that they could integrate with the AR art. Another possible extension could be to change the augmentations from time to time, either when the artist wanted to refresh the artwork, or for a specific occasion. This would make the AR art even more dynamic, as it would constantly evolve. For example, the set of markers could be changed to refer to a specific event or they could follow a theme. The markers could also be changed after what time of the day it was or by the height of the audience, to be especially designed for kids.

Further research in AR art when it comes to collaboration could also be interesting. As we saw during the evaluation session with two users, users behave differently when interacting collaborative than alone. Collaborative AR art could also open up for new user experiences when it comes to users interacting with the artwork and creating something new together.

6.4 Summary of the chapter

This chapter concluded the thesis, by giving a summary of the thesis and the answers to the research questions and presenting the main results of the study. The study was thereafter reflected upon, and further research both on ARTree and the area of augmented reality art was suggested.

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Appendix A: Evaluation of ARTree - Consent form

Information about the project

You are asked to be a part of the evaluation of ARTree. ARTree is a project researching the user experience of the technology augmented reality in art. The purpose of the evaluation is to get an understanding of how users interact with augmented reality art.

Use of data

The data collected from the evaluation will be used in a master thesis as well as in an article. The evaluation session will be video taped, and screen shots may be used. You may be quoted, however, your name will not be identified.

The evaluation

The evaluation will take approximately 15 minutes. During the evaluation, you are asked to "think aloud", in form of expressing and explaining your thoughts, actions, experiences, feelings and so on while interacting with ARTree. While doing this, it is important that you are aware of that it is ARTree that is being evaluated – not you or your comments, feel free to act and talk as naturally as possible. You are able to withdraw from the evaluation at any time should you wish to do so.

By signing this you state that you agree to all of the above. Your contribution is highly appreciated, thank you!

___________________________________ _____________

Signature of participant Date

Appendix B: Evaluation of ARTree – Questionnaire

Evaluator number: _______

Age: _______

	Yes	No
Do you have previous knowledge about augmented reality?	☐	☐

If yes, to what extent (heard of/ studied/ developed and so on)?

____

____

	Yes	No
Have you ever used an augmented reality system or application?	☐	☐

If yes, what kind?

____

____

	Yes	No
Have you ever experienced any kind of digital or interactive art?	☐	☐

If yes, what kind?

____

____

Appendix C: Answers from questionnaires

The numbers refer to evaluator number.

Age:

1: 27

2: 27

3: 23

4: 24

5: Not answered

Do you have previous knowledge about augmented reality?

If yes, to what extent (heard of/ studied/ developed and so on)?

1: No

2: No

3: Yes, heard of

4: Yes, heard of

5: Yes, heard of

Have you ever used an augmented reality system or application? If yes, what kind?

1: No

2: No

3: No

4: No

5: No

Have you ever experienced any kind of digital or interactive art? If yes, what kind?

1: No

2: Yes, installations

3: No

4: No

5: Yes, different kinds