Exploring Place and Direction: Mobile Augmented Reality in the Astrid Lindgren Landscape

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ABSTRACT
This paper describes the design process and user evaluation of an outdoor educational mobile augmented reality application. The main goal was to enhance and augment the experience of a visit to a culturally significant place, the childhood home of the children's book author Astrid Lindgren. Visiting sites of historical significance is not limited to the cultural experience itself, but can be seen as an opportunity for learning and exploring a place as it is now and as it has been in past times. By investigating the two design dimensions place and time, our application was conceived as a treasure hunt, where users activate content by moving between places and pointing the mobile device in different directions or at different markers. The application was field tested with mixed groups of children and adults. The evaluation indicates that the prototype did encourage both learning and exploring, which also was the design objective.

Author Keywords
Augmented reality, Mobile augmented reality, Qualitative user study, Contextual learning

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Being outdoors exploring nature or the urban area, you are surrounded by natural objects and artefacts that have meaning and a hidden history. Having a guide walking alongside you can enhance your experience and inform you about the objects and their origin. However, having a personal guide by your side 24/7 is, naturally, impractical and expensive. By employing new technologies, like mobile Augmented Reality (AR), a human guide can be replaced or augmented by a smartphone application that provides such contextual information. This paper describes the design process of the Minnesmark outdoor education application framework for mobile devices. The main goal of the system is to enhance and augment the experience of a visit to a culturally significant place. Visiting sites of cultural value is not limited to the cultural experience itself, but can also be seen as an opportunity to learn and explore. The paper presents the initial design stages of the Minnesmark framework the final prototype evaluation of the application called "Astrid's spår" (eng., Astrid's Steps), which was built based on the framework.

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BACKGROUND
Astrid Lindgren is one of Sweden's most read and beloved children book authors. Many characters in the books are based on her childhood memories and the natural surroundings of Småland, Sweden. Her childhood home, Näs, located in Vimmerby, is a popular destination for adults and children. Visitors come to Näs and Vimmerby to explore the real life settings of her famous stories and characters, but also to see her home, and the surroundings that inspired her creations. The aim of this paper is to describe the process of creating a mobile AR application that allows visitors to explore this area in new and different ways that encourage playful exploration and curiosity.

Mobile Augmented Reality
Augmented Reality is part of what Milgram and Kishino (1994) referred to as the virtual continuum, which is used to describe the gradual transition from the real world to the completely virtual world. Traditionally, AR systems have been more or less wearable computers with head-mounted displays and one or more interaction devices (voice, buttons, gestures etc.). There have been numerous AR applications developed in diverse domains like manufacturing, gaming and the military. Historically, AR applications have mainly been developed as part of research and, hence, rarely became consumer products. This changed with the introduction of smart phones.

Mobile Augmented Reality has exploded in terms of available applications over the past couple of years, but the idea of mobile AR is not new. Pyssysalo et al. (2000) presented a prototype of a "future mobile phone called CyPhone". The idea was to build a phone that could not only do voice calls, but also support context specific and multi-user multimedia services much like the smartphones is used today (however, the CyPhone prototype also included a wearable computer and a head-mounted display rather than a one-piece hand held touch screen interface).

The use of wearable computers and mobile phones as platforms for AR has been explored for a long time, for instance to support maintenance of power plants (Klinker et al., 2001), for outdoor and indoor navigation (Reitmayr and Schmalstieg, 2003), mobile phone games (Henrysson et al., 2005), and museum guides (Schmalstieg and Wagner, 2007).

The use of smartphones has increased the availability and accessibility of AR applications to a wider public. However, there is still a need for more qualitative contextual studies and field trials in this area. Morrison et al. (2011) describe two field trials of an AR application called MapLens, where a "magic lens" augments paper-based city maps. This concept is not unlike the spatially aware handheld device concept described by Olwal (2005), where AR technology was used to give information in context. The MapLens studies (Morrison, 2011) focused on evaluating the use of AR for small-group collaborative tasks. The results of the study indicated that users of AR applications tend to use them for creating common ground in their communication.

Contextual Design Experiences

One of the main benefits of AR is the possibility to present information directly to the user in relation to the actual physical surroundings in which he/she is embedded. For instance, AR applications can be used to give instructions and overlay instructional information (texts, animations etc.) directly in the user's field of view. This feature of AR minimizes the amount of time spent interacting with the device rather than working on the task itself. In a similar way, walking through a museum wearing headphones or listening to a guide that explains what you are seeing adds an extra dimension to the experience. Liestøl (2009, 2010) call these types of AR experiences situated simulations. Situated simulations are a design genre that requires a 3G smartphone with graphic capabilities, GPS positioning, an accelerometer and an electronic compass (Liestøl, 2009). By using this hardware it is possible to create a combination of two different perspectives, for instance, layering a historical view on top of a phone's camera view of the surroundings. Another example of using mobile devices for augmented cultural experiences is provided by the Westwood project. Here is an audio guide used in combination with visual augmentations on a mobile phone to amplify certain points of interest during a guided tour in Westwood, California (Wither et al., 2010).

Outdoor Education and Contextual Learning

Mobile experiences can be more than entertainment; they can also be powerful tools for learning. AR systems can support different types of learning such as *skill training* as exemplified for instance as a simulation and visualisation tool in the medical field (Weidenbach et al., 2000) and for assembly tasks (Boud et al., 1999; Nilsson and Johansson, 2008). Another type of learning is *discovery-based learning* which is based on constructivist theories, where activity-based interactions is used to improve learning and understanding. Discovery-based learning has been illustrated by projects focused on understanding of spatial relationships as exemplified in engineering graphics education (Martín-Gutiérrez et al., 2010) and for collaborative learning in mathematics and geometry by Kaufmann and Schmalstieg (2003).

Taking education out of the classroom enables direct interactions between theoretical information and practical experience, for instance by placing historical information directly in its physical context. Imortantly, place-based education recognizes a student's local community as a source of information and place for learning. Hence, the local culture, its history and natural milieu are emphasised (Løvlie, 2007). Moreover, we learn not only by seeing and hearing but also by smelling, feeling, tasting and touching; "grip to grasp", is a suiting metaphor to characterize outdoor education (Dahlgren and Szczepanski, 1998).

Games can be a part of discovery-based and place-based learning. Wu and colleagues have presented an example of how mobile treasure hunts can be used to teach students on historical and cultural events in the Five-Harbour District of Tainan, Taiwan (Wu et al., 2010). In other subject areas, like biology end ecology, taking students to the countryside rather than bringing the flora and fauna into the classroom can enable an experience similar to the historical treasure hunt. AR has been used in science centres and museum exhibits at several places, for instance in New Zealand as described by Woods et al. (2004). The experience from these projects has been that the applications have received much positive feedback and that they hold true potential for education. AR allows spatial, temporal and contextual conceptualisation and exploration which benefits learning.

The aim of this project was to create an interactive experience to support outdoor education at the places that influenced the writings and stories of Astrid Lindgren. These places are not only confined to actual buildings and physical places but include also cultural references and mythology. The specific research problems concerned the choice of design concepts to stimulate learning and how these concepts should materialize in a design and prototype.

DESIGN PROCESS

The project as a whole followed an iterative design process with evolutionary prototyping (Floyd, 1984). We held a series of initial workshops to define the boundaries of the project, the ideation concepts and to establish the criteria for the technological solution. These workshops

were based on a Participatory Design approach (Bødker and Grønbæk, 1991). The workshops and the early use case scenarios that were developed focused on themes like historical and cultural values, nature, costs, physical place-based interaction and visitors' group activities. These themes formed preliminary criteria for the design. The initial ideation was cooperative insofar that researchers and designers worked together with outdoors educators to develop a set of design concepts. The workshops focussed on use scenarios and several potential user personas were also discussed. In total, 39 design concepts were documented from these initial workshops.

After the initial workshops, a set of eight design concepts, which were considered more promising than the others, were developed in more detail. The details of these design concepts were specified in scenarios and storyboards and evaluated by the cooperative design team (again with researchers, designers and outdoors educators) in relation to the initial design criteria from the first phase. The selected concept eventually became a synthesis of several design alternatives. The detailed design was finally specified using storyboarding, implemented in a prototype and evaluated through an end user study at Astrid Lindgren's childhood home Näs.

Design Concepts

The eight design concepts that were chosen for further evaluation represented different kinds of design solutions. These concepts functioned as models that gave a good coverage of the design space and that could provide a solid foundation for making syntheses:

The Time Machine (Figure 1): At special places, the visitor point the phone camera towards a scenery and the phone shows how the place used to look like historically. A slider is used to sweep through different time periods. The Time Machine belonged to a category of concepts that gave the visitors some kind of "super vision".

Figure 1. The Time Machine design concept.

The Walking Quiz (Figure 2): A treasure map shows where the user is situated and where the questions are spatially placed. The latter places can also have other challenges - not only questions. The Walking Quiz was one of several games that were explored.

Figure 2. The Walking Quiz concept.

The Show and Tell Guide (Figure 3): A guide who wants to show something to a guide group holds up a visual marker and the visitors point their mobile phone cameras towards the marker to start a multimedia illustration of what the guide is talking about. Show and Tell was one of the concepts that focused on guiding groups of visitors.

Figure 3. The Show and Tell Guide.

The Interactive Map (Figure 4): A printed visitors' map where hidden information about interesting sites is displayed when it is viewed through the mobile phone. The map can be sent to visitors' home before they arrive to the actual site to foster interest and build expectations. Several other concepts also focused on the phases before and after the visit.

Figure 4. The Interactive Map design concept.

The Sidekick (Figure 5): A little helper to the guide that can be used to dramatize a guided tour. The guide carries a visual marker and the visitor can see the sidekick when the phone camera is pointing towards the guide. This concept was one of many that made use of interactive characters of some sort.

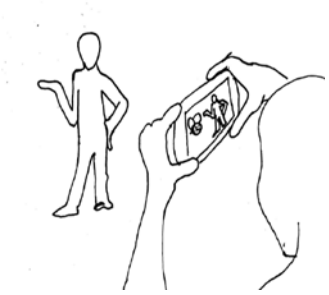

Figure 5. The Sidekick design concept.

Mythical Creatures (Figure 6): Creatures and characters from Astrid Lindgren's books roam around in the landscape. To see them, the visitor needs to look at the landscape through their mobile phone. The visitors can try to take a photo of them, if they are not too quick. The Mythical Creatures concept was one example of several concepts that focused on taking photos.

Figure 6. The Mythical Creatures concept.

The Spatial Audiobook (Figure 7): Simply by walking around the area where Astrid Lindgren grew up, visitors hear stories about the things they see. If they direct phone camera at a specific tree, for example, the story about the tree is told. This concept was one of several that made use of storytelling.

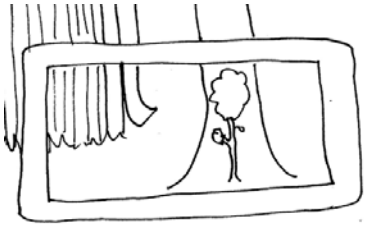

Figure 7. The Spatial Audiobook design concept.

Leaving Traces (Figure 8): Visitors can write notes and leave photos that are geographically tagged at specific places for others to find with their phones. Several concepts explored the idea of leaving traces at a site you visit.

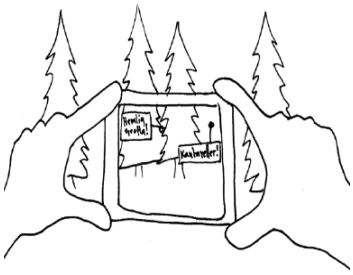

Figure 8. The Leaving Traces design concept.

These eight concepts were compared and evaluated against the project criteria, syntheses were made, and features of several of them were redefined into two main design concepts:

- The Spatial Audiobook combined with the Interactive Map and Walking Quiz and,
- The Show and Tell Guide.

It was identified that the functions needed for the Spatial Audiobook and the Interactive Map could also be used to implement the Show and Tell guide. For this reason the first round of prototypes focused on the Spatial Audiobook and the Interactive Map. These concepts were further developed in detail using storyboarding.

Storyboarding

A first storyboard was made to specify the functionality and the basic requirements on the application. A second storyboard (see Figure 9) was created to direct the user interface design and the content development. This storyboard was based on the previous design concepts and visualised detailed versions of the chosen ideas.

Figure 9. An excerpt of the high-level storyboard for the show and tell guide concept.

The excerpt in Figure 9 describes how the guide, who wants to illustrate something, holds up a marker that allows people in the visitor group to see images and videos sequences.

The storyboards were then refined and evaluated in order to extract and decide how to integrate the chosen concepts. A new storyboard was developed which combined the previous ideas (Figure 10).

Figure 10. Excerpt from the combined concept storyboard.

The excerpt in Figure 10 is part of a storyboard describing how the user starts the application in the reception area, receives a treasure map, and hears a story when Astrid and her brother Gunnar searched for treasures as children. The users can see hidden things on the map when they view it through the phone display. In this instance, the users' quest is to find ingredients to cook a dinner.

The storyboard describes how visitors walk from station to station to gather the ingredients needed by listening to a story about the things they see and, hence, getting an opportunity to explore and discover things at the different stations. A basic idea was to let them see things that cannot normally be seen. For example, what it looks like inside the hollow tree, the old grocery store from the perspective of a mouse, or the landscape from the rooftop of Astrid Lindgren's childhood home. This part of the design process also included design of a low-fidelity prototype. A walkthrough of a Lo-Fi prototype of the application was also conducted. Arvola et al. (2012) describe this evaluation is detail.

High Fidelity Prototype

In parallel with the conceptual and detailed design of the application the technical platform was developed based on the ideas from the workshops. The first high fidelity prototype framework for Minnesmark was developed for the iPhone and iOS and was based on the experiences from the evaluation of the lo-fi prototype (Figure 11).

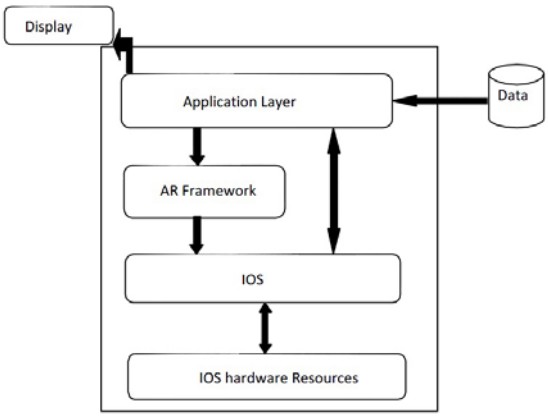

Figure 11. The software architecture of Minnesmark

The iPhone provides the necessary sensors: GPS, accelerometer, gyroscope, compass and camera. The AR ToolKit (Kato and Billinghurst, 2004) provided the marker tracking needed for the augmented reality features. The focus of the Minnesmark framework is on the application layer, where support for three different types of data is handled (e.g., visual patterns detected by ARToolKit, multimedia content, and 3D models). A new application based on the framework can put together quickly using JSON-scripts (JavaScript Object Notation). The current implementation is client-based, but the aim for the future is to have as little data and functionality as possible on the client, to facilitate porting the system to other platforms such as Android and Windows Mobile.

Interaction by directions and places

The fundamental interaction design idea of Minnesmark, and the application Astrid's spår, is that visitors interact with the computer-augmented landscape by walking in it and point their mobile phone camera towards different objects and sceneries to discover hidden stories and information in the form of multimedia (Figure 12).

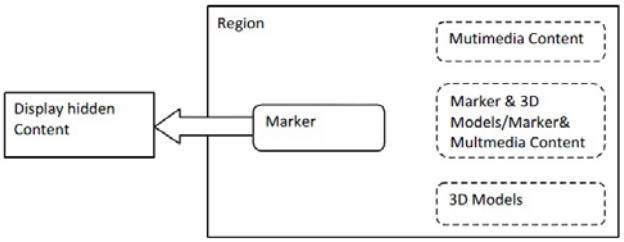

Figure 12. A schematic of the application Astrid's spår.

The application includes five different spatial regions that are detected by the GPS. Each region that the user enters triggers different types of content. Some regions have audio and video sequences that are activated as the user enters the region; other content is hidden until the user intentionally aims the camera at a visual marker.

When the camera is held parallel to ground, with the screen up, an arrow pointing to the next interesting place is shown. When they hold the camera towards the landscape around them different media is presented. Other media objects are presented on the screen when visitors direct the camera towards visual markers on the printed map or on signs in the environment. The only time a visitor needs to tap the screen is when starting and closing the application, and when viewing panoramic images at one station. The rationale for this design decision is that the visitors' should focus on the surroundings rather than interacting with a phone.

USER EVALUATION OF THE PROTOTYPE

In order to evaluate the final prototype, a contextual user study was conducted at Näs, Astrid Lindgren's childhood home. The study was planned and conducted as a part of a university student project.

Astrid's Steps – A Treasure Hunt

The application designed for the study was based on the show and tell and audiobook concepts described above. It was designed as a treasure hunt in order to allow playful guided tours of the surroundings at Näs. The aim for the users was to visit a number of places of interest, and at these locations they were presented with a food ingredient. After visiting all places in the guide, they

collected all the ingredients for a classic type of food (pancakes).

The information in the application was presented in the form of images, audio clips and videos as well as 3D models. The video clips in the application were 3 minutes maximum and about the author in her younger years. A panoramic image was used to mimic the author's experience of standing on the roof of home looking over the surroundings – an experience described, from a child's perspective, in several of her books. A 3D model was used to give the users the possibility to look around inside the kitchen where Astrid spent a lot of time as a child. Animated arrows showed the way to the next ingredient until the users were back where they started. At this final point they received an image of the finished pancakes.

The application was designed to be an interactive game that allowed for collaboration and exploration. Since the application was run on a handheld device, the aim was also to give the user a feeling of looking through a peephole into another world.

Participants

The intended user group for the application is tourists at Astrid Lindgren's Näs. The main groups that spend time in this area are families with children of all ages. As a result, we aimed for a similar composition and the participants in the study were a mixture of adults and children between the ages of four and thirteen. In total 20 participants (15 children and 5 adults) took part in the study. Most of the participants had previous experiences with touch-interfaces and mobile phone applications and all but two of them had visited Astrid Lindgren's Näs before. A few of them visited Näs regularly.

Method

In order to evaluate the prototype in its intended usage environment and by the intended user group, the study was conducted in the natural setting at Näs. The participants conducted the treasure hunt in groups of two to four (seven groups in total), collaborating and sharing an iPhone and a map with markers depicting the route.

The instructions for the study were presented verbally to each group and they were also presented with an information poster with instructions. The users were informed that the task at hand was to collect food ingredients along a path and to try to figure out what food they were collecting ingredients for. After they had received the instructions they were allowed to test the application – starting it up and holding it over the map with markers (Figure 13).

After testing the application for a few minutes they were instructed to begin the treasure hunt. The participants were also informed that if they had any questions or problems with the application one of the project members would assist them during the wsalk.

Figure 13. The map with markers.

Data Collection and Analysis

All participants were observed by one of our project members throughout the treasure hunt. The observer was allowed to answer questions of technical nature but did not interfere in solving the tasks. The observers used a protocol for note taking which included the following points for observation:

- Indicators of difficulties/fun/ease/frustration
- Difficulties of using the device
- Difficulties of seeing the display
- Marker tracking issues
- Questions asked about the application
- Procedures for cooperation and turn-taking
- Focus on the display or the surroundings

After a group had finished the treasure hunt a group interview was held. The interview began with questions about age and previous experiences with the place and mobile phone applications. After these introductory questions, an interview guide with approximately 15 questions (plus some follow-up questions when necessary) was used. The questions covered the following themes:

- Background knowledge about Astrid Lindgren's Näs
- Activities that the participants engage in together with their families
- Experiences from the treasure hunt
- Usability issues
- Collaborative issues
- Media content

Since most of the participants were young children, the interview questions were modified accordingly (Doverberg and Pramling Samuelsson, 2000).

The collected data was analyzed using a qualitative approach influenced by grounded theory. An open transcription of the material was conducted before the text was categorized into themes.

Results

The analysis of the interviews showed that there were a number of important aspects of the treasure hunt application: Collaboration, entertainment value, technical issues and general observations.

Collaboration

Since the application was running on a smartphone, the rather limited screen space encouraged the participants to stay close together when figuring out what step to take and which direction to walk. Even though it was difficult for everyone in the group to see the screen at the same time they seemingly managed to share it. Our observations and interviews also showed that a child generally was in charge of the phone rather than the adult in the group.

The interviews indicate that the participants used collaborative strategies to solve the tasks and that they ensured that all member of the group got a chance to interact with the application and be a part of the treasure hunt. Adapting to each others movements, the grown-ups tended to kneel down and other spontaneous turn-taking actions was frequent when using the phone. The collaboration was observed to be difficult in a group of four children where no adults participated. One reason can be that there was no adult there to help managing turn-taking, but it may also be that it simply is difficult for four people to cooperate around a small screen.

Entertainment Value

When asked about what was most entertaining or fun in the application several groups mentioned a specific video (of a doll being thrown into the air), but participants also appreciated the panoramic rooftop view of the surroundings. The stories in the short videos were also considered a positive aspect since they also were informative and allowed the participants to learn more about the author and her life.

The still images that popped up at some places were perceived as slightly pointless by several of the children. This pointlessness, however, amused them as they thought it was funny when they popped up in what they felt was out of context.

Technical Issues and Other Difficulties

The least appreciated aspect of the application was quite naturally some technical malfunctions and a couple of incidents when the application shut down unexpectedly. Some of the participants experienced the treasure hunt as being to easy and not challenging enough, and others thought it was too short.

There were some differences between the adult's and the children's difficulties with the application. In general the children were quicker to understand and start using the application, but they sometimes interpreted the instructions literally. For example, one young participant noted that it sometimes was impossible to follow the arrow as it pointed into a bush. Rather than taking the arrow as a general direction they wanted to follow its direct path. However, this was usually resolved with the aid of the older participants in the group.

Another issue that differed between age groups was the logic behind some of the ingredients they collected. One part of the task was to gather wood for the stove. Of course few children had any experience of having to gather wood in order to fire up a stove, so they did not understand the connection between this "ingredient" and the rest of the collection.

General Observations

The main difficulty observed during the study was to interpret the direction by aid of the arrows used in the application. On many occasions the participants used the regular map to find their way to the next interesting place, where they found the markers quite easily. Many did accordingly not use the direction arrow that was shown when the camera of the device pointed towards the ground.

The fact that the participants were both children and adults gave an interesting dynamic to both the use of the application and the user study. Having a familiar adult with them alleviated the fact that the children were sometimes shy in front of the observer/interviewer. When they were too shy to answer a question the adult in their group would repeat the question and the child would then happily answer him or her instead.

Discussion of the User Study

In general the participants seemed to clearly enjoy the treasure hunt and had fun while doing it. It was perceived to be a fun way of collaborating and learning more about Astrid Lindgren and her life.

The obstacles the participants met along the way were handled through communication and further exploration. Several of the children expressed that they had fun while walking around and that they did find out more about Astrid Lindgren and Näs.

Several of the participants had extensive previous experience of the location and knowledge about the author before they took part of this study. Nevertheless they thought it was a learning experience that held entertainment value and this shows a promise for the concept as a part of future tourist-aimed activities in Näs.

The initial objectives of the project – creating a learning application that encourages exploration of the landscape – did come through in the design of the application. The user study itself illustrated collaborative aspects of the application and how the participants developed strategies for collaboration.

CONCLUSIONS AND FUTURE WORK

In this project several design concepts for mobile AR for outdoor education have been explored. A synthesis of some of these concepts was put to test in a prototype and a user evaluation at Näs, Astrid Lindgren's childhood home. The results show that AR treasure hunts can be a way of telling stories about culturally significant places.

A technical lesson learned is that the Minnesmark framework allows for rapid development of new applications using JSON-scripts (the applications layer in Figure 11). Based on the framework, it is not difficult to augment another place. The key feature of the framework that allows the rapid development is the choice to build applications in a script language like JSON, and that the application layer is freestanding from the rest of the framework.

Minnesmark is also good at integrating multiple sensors and multiple media forms in one application. This means that it allows an application to switch between showing films, displaying images, place 3D-objects on top of markers, or navigate a panorama using the gyroscope and accelerometer. It is the freestanding applications layer in Minnesmark that allows for this integration.

The project set out to develop means for place-based outdoor education. We designed such means using mobile augmented reality in the landscape of Astrid Lindgren. The design relied on supporting principles from outdoor education by facilitating direct physical contact with nature and culture, allowing visitor both experience and reflection at authentic places. The aim has been to provide people with the experience of 'this is where it happened'. Such experiences are developed through activity in a natural and cultural environment that supplies the content of learning.

The idea of interaction with, and within, the computer-augmented landscape by using directions and places as triggering events aims at keeping the application and mobile device in the background of attention. In this way people are allowed to focus on the environment and its stories and memories.

Future work will primarily focus on constructing other AR applications using the Minnesmark framework with the aim to explore further uses of mobile augmented reality in place-based education and tourism. In the first iteration of the system development held everything on the client side. However, future development will focus on a full client-server architecture. Morover, there is also a need to facilitate content management in Minnesmark to make it easy for users to set up new computer-augmented landscapes.

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