GARfiti

An augmented reality collaborative painting app

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ABSTRACT
This paper describes the development of an android application for the Museum of World Culture in Gothenburg, Sweden. Using augmented reality, the application enables the user to paint on a virtual canvas projected onto the physical space through the user's handheld device. The paper accounts for the design process, the challenges involved and the state of the final prototype.

AUTHOR KEYWORDS
Augmented Reality, Android, Vuforia, Världskulturmuseet

BACKGROUND
The Museum of World Culture, located in Gothenburg, Sweden, has the purpose of "displaying and bringing to life the various cultures of our world, in particular cultures outside of Sweden" [1]. However, the museum is currently not utilizing all the space it has at its disposal. There is for example a basement that is currently empty, save for a lone projector displaying a slideshow of pictures. There is also a lack of ways for the visitors to participate, and to express their own creativity. Children are encouraged to draw a few paintings in the *Tillsammans* exhibition, but other than that there are no other exhibits that promote creativity through interactivity.

Another organization in Gothenburg that has provided people with a means of expressing their creativity is Röda Sten Konsthall that have opened up a public wall where anyone is allowed to paint graffiti [2]. This wall is constantly changing in appearance as the visitors paint on top of what's previously been painted, creating a space that evolves along its guests, vibrant and colorful in its expression.

INTRODUCTION
The aim of this project is to find a suitable way of incorporating the freedom of expression from the legal graffiti wall into the exhibition space at the museum of world culture. The visitors should have a means of expressing their thoughts and feelings in a manner that is non-destructive and at the same time entertaining.

As this project is part of a course in mobile computing the final result will take the form of an Android application. The application will be a collaborative drawing application that utilizes Augmented Reality (AR) technology to make the canvas appear in the user's real life surroundings. This will be achieved by using the Vuforia platform. AR is technology that provides a real time view of the user's immediate surrounding and enhances it with digital content or information.

CONCEPT
The concept is an AR application for Android smartphones that the visitors of the museum can use to access an open virtual canvas. This canvas is only visible on the screen of the visitors phones when they are scanning a so called Image Target mounted on the walls of the museum. Image targets are a part of the vuforia platform, these can be any two dimensional image as long as they meet certain requirements. The application identifies these targets and a canvas will appear in front of the user on the wall where the image target is located, obscuring anything behind it. The idea is that each visitor is free to draw or write anything using their fingers as the input device. This canvas is the same for all users of the app, meaning that anything that a user draws on the canvas is stored in a database and is sent to any other user that scans the same image target. The purpose of this is to encourage the users to continue where other visitors left off and also to collaborate. It is also a way to allow users to collectively moderate the content, should someone draw or writes something inappropriate then other users can simply remove this by drawing on top of it, reducing the need for external moderation.

Target User Group
The application is targeted at children aged 8 to 12 as the principal functionality is drawing, an activity

mainly performed by younger children. On the other hand the fact that a mobile phone is required it is naturally inferred that the target group needs to have access to and be able to use one. With this in mind the target group has been set to 8 to 12 years as 9 out of 10 swedish 11 year olds have their own smartphone. [3]. This also means that they ought to have at least a basic familiarity with using smartphone applications.

Desired Features

The following list of features is what the application should at the least provide in its finished state.

See the Surroundings on the Screen

The most basic but also a very important feature is to be able to display what is behind the user's phone through the phone's backside camera. Without this feature the application becomes nothing more than a regular drawing application that could be used anywhere.

Scan Image Targets

Scanning Image Targets is necessary in order to be able to know where to display the virtual canvas. Image Targets are similar to Quick Response (QR) codes but they can be any two dimensional image as long as they fulfill certain requirements. This can be both an advantage and a disadvantage as these targets can become part of an exhibition and not stand out as much, but it could also mean that the users do not know which images to scan. This could in the future be solved by including a label that indicates that an image is scannable.

Draw on the Canvas

Another basic but also vital feature, as this is the main activity performed by the users of the application. Drawing is performed by having the users move their fingers across the virtual canvas displayed on the screen. If only part of the canvas is visible on the screen the touch input should be mapped to fit the visible portion of the canvas. This results in a novel way of zooming in or out on the canvas by moving closer to or further away from it.

Shared Canvas

Each image target should represent it's own canvas, and these canvases should in turn display the same content for all users that scan them. Something that is drawn by one user should become visible to any other user scanning the same target. This information should be updated in realtime so that users can see where others are drawing and avoid a situation where they are overlapping each others creations. For this to work a database is necessary to store data regarding where users have painted, which color they've used etc.

Select Different Colors

For the drawing experience to be enjoyable it is necessary that the users have access to a variety of different colors to choose from. Otherwise the canvas will ultimately end up being covered in a single color. The selection of colors should ideally be performed with an AR color palette outside of the virtual canvas. This color palette should be easily understood and prioritize ease of use over complex features such as being able to set individual values for red, green, blue and alpha or other features found in more advanced drawing and image editing software. The users should be able to chose from an array of predetermined colors, with a clear clear visual representation of the currently active color.

Select different brush sizes

Together with the color selection it should also be possible to select the size of the brush used for drawing. Just as with the color selection, ease of use should be prioritized over advanced features.

Database with different Image Targets

If there is to be several image targets all bound to different canvases, these will need to be stored in a database. Vuforia makes it possible to either store these in a cloud database or in a local device database. Vuforia's guidelines state that a device database is appropriate if the database will consist of less than 100 targets [4]. As this is most likely the case for this application a device database was chosen instead of a cloud database. A local database stored on the device is capable of faster recognition and reduces the applications reliance on network speed, which is also desirable.

DESIGN AND WORK PROCESS

The following section will in detail describe the work process throughout the project, as well the design decisions that has been taken during the course of the work.

Ideation

For ideation, a 5W's (What, Where, Who, When and Why) approach was used. In a series of sessions three of these - where, when and who - were specified at a time, and the team then performed simple brainstorming to come up with the what and why.

The resulting ideas were then ranked by discussion, weighing in the needs of the Museum of World Culture, feasibility and personal interest, placing each into one of three categories: "Yes please", "Sure, ok" and "Whatever". The three top ideas were then picked for further development.

Challenges

During the early stages of development, the team decided to go with a coding approach where

high-level API libraries were going to be avoided in favour of low level coding. This meant better-tailored software that would run faster on mobile devices and without any superfluous features. While beneficial for performance and usability, it also means that more developing resources need to be put into crafting the whole system and hunting down any possible bugs and glitches that may arise. This turned out to be a problem because of the amount of effort that was put into the development of several algorithms that manually modified memory locations with low-level system calls. Due to the time spent on this, a considerable amount of features needed to be cut from the final prototype. These features are further discussed in the *Future work* section.

RESULT

The end result is an application that provides the features previously listed, although many of them are implemented in a basic manner. The user sees the room he or she is in through the phone's camera. When the user views an image target stored in the application's database through the camera, the virtual canvas appears as though it was mounted where the target is. This canvas displays what previous and current users of the application has drawn as the canvas content coordinated with the database. This database contains information regarding the coordinates, the color and the size of each brush stroke. All devices running the application listen for additions to the database and receives the new brush stroke as soon as it is added. The color is currently selected using a slider that is corresponding to a list of colors. The brush size is similarly selected using a slider but with discrete values representing the radius of the brush stroke.

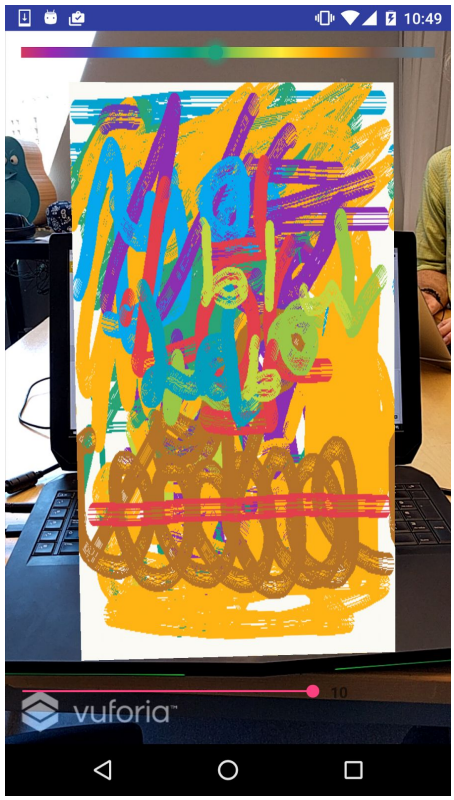

Figure 1. Screenshot of the application GUI. At the top is a slider acting as color palette. Close to the bottom is another slider providing brush size optionality.

DISCUSSION

Unity

The question why we did not Unity as a graphics engine for the implementation is a valid one. Vuforia has built in Unity support and it would have simplified the process of developing the app by abstracting away a lot of the underlying matrix calculations. It would also have facilitated the polishing of the graphic exterior. This choice is partly due to us seeing this as an android course, and therefore wanting to keep it as native as possible. The other reason is that we wanted to develop an understanding for the underlying mechanisms involved. Implementing it ourselves also meant familiar code with less bells and whistles, which might speed up the running of the application. It not being optimized might, however, result the opposite.

Using Unity would have speeded up development considerably. As a comparison, late in the project a test implementation in Unity was made. In one half day, the state of the test application was that of three weeks of development of the android only version. This was of course using the knowledge gained over those weeks.

The desire for under the hood work also meant we favored own implementations over some standard android classes. This meant implementing our own line drawing and brush filling algorithms.

FUTURE WORK

The final prototype had very stable functionality along with solid features that successfully demonstrated the capabilities of the project's scope. Nevertheless, there are still a lot of extensive functionalities that the development team would like to incorporate. The following is a list of such features along with a brief explanation:

- A selection of different brushes: the users will be able to interact with a simple overlay menu to choose the brush texture that goes best with their artwork.
- Virtual color palette: this is one of the most important extra features. In the prototype, the color is selected by using a limited slider on top of the viewport. The development team wants to implement a virtual AR palette that can be used intuitively to mix and select colors just as in real life.
- Paint the whole room: the core idea behind the project was to have museum visitors painting every inch of the walls in the basement of the Museum of World Culture, and this idea hasn't been abandoned. The technology involving augmented reality is fairly new and ways of mapping a whole room are still being researched. Until then, the team will focus on offering a believable virtual canvas object on screen.
- Timelapse of collaborative canvas: the development group thinks that it is very important for the users to not only get a glimpse of the current state of the canvas, but also to be able to see the evolution of it since the application became public. This will hopefully provide a sense of belonging as the user will appreciate how his or her drawings changed the canvas as a whole over time.
- More realistic virtual canvas object: the current application holds a basic canvas mesh that is not shaded to appear as a real object. A better canvas object needs to be developed for as long as painting the whole room remains implausible; this would require the use of an easel, soft shadows and a coarse material texture that resembles a real canvas.

CONCLUSION

The aims of the project were to increase the interactivity of the museum, utilize the basement space and give the Museum of World Culture a technology update. The final prototype of the application addresses these issues to a somewhat satisfactory extent, but leaves some things to be desired in the way of aesthetics and functionality.

Although it was interesting and educational to take such a technically challenging approach of implementing as much as possible from scratch, it did have the effect of limiting the end result.

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