

# 3D Design for Augmented Reality

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**Abstract.** How do you define a good concept when designing augmented reality apps for mobiles? This paper focuses on design processes technically, graphically and conceptually in the development of 3D content for Augmented Reality on mobile devices. Based on experiences in the development and implementation of a course in 3D design for Augmented Reality at NITH (The Norwegian School of IT), challenges and methods in creating concepts, optimized graphics and visually coherent content for AR will be discussed.

**Keywords:** Augmented Reality, Virtual Reality, Mixed reality, Education, 3D design, Concepts, Presence in augmented and virtual reality.

## 1 Introduction

With the increased use of smart phones and tablets, development of Augmented Reality apps for a wide range of use has increased. Numerous games with AR content are available on Google Play and the App Store. There is a significant yearly increase in the amount of research being conducted on AR technology. According to numbers from Google Scholar [1], articles on augmented reality have risen from 4,020 in 2008 to 5,920 in 2010, 9,200 in 2012 and finally 11,500 in 2013. The numbers from Google Scholar may vary depending on search criteria. A similar search was done by Geroinenko in 2012 [2] with a different result, but the trend is similar. It seems that it is a technology that, to mention a few, is embraced by disciplines ranging from research, art and entertainment to marketing, architecture, engineering, military and medicine. A common impression is that most research on the topic still tries to enhance the technology, but the industry has also, to some degree, started to use AR concepts. As an example when Volkswagen launched their concept car, XL1 2014, an AR app by the German company Metaio [17] was developed [3]. By pointing the camera of a cell phone against the open engine room, the user can trigger animations displaying maintenance instructions superimposed on the camera image of the engine.

Augmented Reality as concept triggers the normal question about what AR is. The focus of this paper will not go into a long discussion about definitions. Wikipedia has one definition [4] that covers a wide range of different technical solutions and concepts. Stating the following: "**Augmented reality (AR)** is a live, copy, view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPS data.". The key issue is the merging of the "real reality" with the "virtual reality", speaking in

the same language as Geroimenko [1]. In this paper, "real reality" as camera images from a mobile device merged with "virtual reality" as 3D graphical scenes. So to refine this paper, it will focus on augmented reality for mobile with the merging of 3D graphics and real time camera images of the mobile device.

As an example the new Google Glasses would be covered under the definition as they have a potential to merge text information with real-world environment through the glasses will not be covered.

## 2 Background

The first Augmented Reality interface dates back to the 1960's with a head mounted display called "sword of Damocles" by Ivan Sutherland [5].

In the beginning, creating AR applications required a massive setup of hardware and custom work. A pioneer project in Norway was the research of AHO (The Oslo School of Architecture and Design) regarding the visualization of the Margaretha Church in Maridalen, Oslo in 2005[6]. The project was a recreation of an old church in 3D. The ruins of the church were covered by markers in order to project the 3D model in the right place [Ill.1]. The project was viewed from a custom made portable screen that the viewer could carry around the area.



**Fig. 1.** Ill. 1. Margaretha Church ruins covered with AR markers

With today's tools for developing AR apps and the spread of smart phones and tablets, it is no longer a big technical challenge to make AR apps if only thinking in

terms of making graphics superimposed with a camera image on a mobile device. Tools for making AR such as Unity 3D with the Vuforia packages makes it easier, but there are still technical challenges. More or less, the same technical research topics are outlined in the 2008 paper, "Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR" [7] are still relevant, such as tracking and how to represent realistic virtual graphics. There are also still limitations when developing AR when it comes to hardware and graphical possibilities. Another challenge lies in designing the content of AR apps visually and conceptually. Which choices do designers make on how to make good quality graphics? Developing AR concepts leads to a question of how and when to use augmented reality. With the rapid development of apps it is easy to see AR often used as a marketing gimmick or simple entertainment where the fascination of superimposing graphics with camera images can be seen as the main driving force. As the "magic of AR" becomes more advanced, storytelling and content that utilize AR as media becomes increasingly important.

The 3D graphics students of NITH (The Norwegian School of Information Technology) have designed augmented reality apps where they learn about these challenges in their course, "3D Design for Mobile Augmented Reality."

### 3 3D Graphics in Education

The AR course at NITH is an elective course for third year 3D graphic students at the school. It was run for the first time in the autumn of 2012 and developed by NITH, the visual effect company Placebo Effects and Labrat - a company specializing in games for mobile devices. The companies have firsthand experience in developing AR apps for the industry and brought important experiences into the course.

The goal of the course was that the students should learn all steps from start to end in developing a simple Augmented Reality app for either iOS or Android. The main assignment in the course was to develop a concept for an artist or band which would include sound, 3D graphic scenery and figure animation. The 3D content should pop up from a CD cover of the artist/band. This made it ideal to use the CD cover as an image tracker for the augmented reality app. An image tracker for AR is a picture or symbol which the camera on the mobile device would recognize and then be able to place and merge the 3D content into the camera image.

The chosen AR technology for the course was Qualcomm Vuforia packages for the Unity game engine. The choice of using the Vuforia libraries was motivated both because it is free to use and the easy integration with Unity 3D. By using this technology it is possible to upload images to the Vuforia developer website [8] to create image targets.

The course is organized in iterations with three assignments. The first assignment would be the design of an image tracker for the 3D content. The image tracker should both be technically stable and visually coherent with the graphical style of the chosen artist. When designing the marker for the AR app, the students had to make their own design of a CD cover for the artist/band. The importance of making the cover instead of just using an already existing CD cover was mainly a pedagogical issue in order to

get the students to understand how an image marker works. It was also important to introduce the students to the concept of adapting to an existing graphical style in the assignment.

The second assignment was to design the 3D scene for the artist/band together with the working image tracker and the complete AR setup in the game engine. The students had 1 year of experience with 3D graphics, and this assignment was focused on the technical setup in Unity 3D with the Vuforia packages for the AR. On the artistic side, the students were encouraged to follow the graphical style from the image marker and to study the visual concepts of the chosen artist/band. This in order to make a scene that was visually coherent with the marker and applying typical elements as coloring, symbols and design of scenery elements that the given artist/band would use.

The third assignment was the full setup with an animated figure as a cartoony version of the artist/band. The students would typically make the figure both look and move like the original artist.

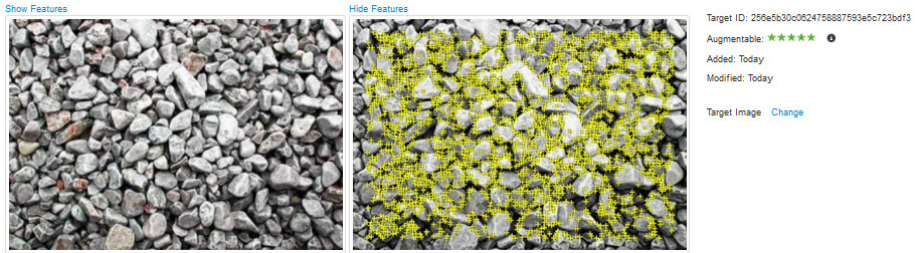
## **4 Design and Artistic Challenges**

### **4.1 Tracking the Scene**

In order to place the virtual scene correctly in place relative to the camera image, there are different techniques available. This will very dependent on the software used. In the course, Qualcomm's Vuforia was chosen as the technology to use. There could be different challenges with other software than those described here.

The Vuforia developer website contains a tool for making image trackers. By uploading an image to be used as a tracker, the tool will show with a rating of stars how good the tracking capabilities are. It will also show the overall distribution of track marks in the image. The technology works by finding contrast and non-repeating patterns in the image. As an example of a very good image tracker is the sample images that follows the Vuforia packages. It is only an image of small stones. However, the image has no repeating pattern and the contrast in and between the stones will distribute tracking marks uniformly over the whole image [III.2.]. The tool on the website will then embed the image into a downloadable Unity package which works directly on an AR camera in the virtual scene.

The challenges lay both in designing a good marker with an even distribution of tracking marks all over the image and to visually represent the artist/band. Another issue to consider is the size of the image marker compared to the virtual scene. For example if the image marker is very small and the virtual scene is very big with an extent far out on the sides of the marker, stability problems could occur, which is described as the pendulum effect, making it difficult to keep the virtual scene steady when watching it together with the "real reality".



**Fig. 2.** Image tracker with rating and evenly distributed tracking marks all over the image

## 4.2 Illuminating the Scene

A key issue in AR is the lighting of the 3D graphics that is supposed to be merged with camera images on the mobile device. In order to have a believable blending between the 3D graphics and the camera images, the first crucial element is how shadows appear in the virtual scene. The problem with realistic lighting in an augmented reality scene is obvious since the camera images in which the virtual scene will be rendered in are not predictable. This means that the coloring, direction and brightness of the lights would be different all the time depending on where the app is used.

There is no doubt of the importance of shadows in a 3D scene. Already in an early paper "The Effect of Shadow Representation in Virtual Objects in Augmented Reality" from 2003 [9], the authors discuss the strong effect of shadows in an augmented reality scene. This is useful, not only for a stronger connection between the real and virtual world but also as an element for creating depth. The paper shows examples with shadows in the virtual scene pre-rendered from one angle. The authors provide tests that show the importance of shadows despite the fact that they would come from an incorrect light direction when rendered together with real time camera images. This leads to the conclusion that it is probably better to have incorrect shadows than none at all.

Newer research has tried to solve the problems with shadow direction. A promising paper titled "Estimation of Environmental Lighting from Known Geometries for Mobile Augmented Reality" [10] discusses how to extract shadow direction based on facial geometry from the camera of the mobile. Still there are problems since the proposed system is only tuned for one light source and is only functional outdoors. In addition, the example seems to only produce sharp shadows.

In computer graphics, a well-known method to obtain photorealistic images is by using HDRI (High dynamic range image) based lighting of the 3D scene. This affects the coloring, direction of shadows and reflections in the scene. This is no longer a big problem to do when it comes to the rendering of 3D graphics for still images or video. Even most commercial game engines have support for using HDRI solutions, which, in computer games, is referred to as HDRR(High dynamic range rendering) [11]. With Augmented Reality, it is different since optimally all light information should be calculated in real time. This is discussed in the paper "Mobile AR Rendering Method using Environmental Light Source Information" [12]. The authors describe a system

for capturing light sources and images from the cameras of a cell phone. The system also uses the gyro in the phone for direction of lights related to the image tracker of the virtual scene. Finally, the captured images would be used as an environmental light for the virtual scene. The method seems promising with multiple soft shadows generated in the scene.

## 5 Industrial Implications

### 5.1 AR Concepts

Developing good concepts for AR where the content, story and technical aspects of AR fully utilize the media can be a challenge. The mentioned car maintenance AR app by Volkswagen combines the actual car with important information on the user's own car and can be used in any place the car would be. Another good example is how the Norwegian dairy producer Tine utilizes the medium with their AR milk marketing campaign. The TineMelk AR app was created by Placebo Effects and Labrat in collaboration with the Try advertising agency.

In an interview, Kim Baumann Larsen shared his thoughts on developing engaging AR concepts and storytelling for the TineMelk AR app. His insight was also presented at Siggraph Asia 2013 [13] and ACM Siggraph 2012 [14]. Tine had, in several TV commercials, established a story world wherein computer-animated, highly photo-realistic cows talked to each other with different Norwegian dialects in the cultural landscapes of Norway.

The most common arena for consuming milk would be the breakfast table. For the second AR app for Tine, a more interactive AR app was designed by Baumann Larsen. By having the milk carton as AR marker children can start a 3D coloring game where they colorize a farm scene with a stylized barn that drops down onto their milk carton. Animated cows will walk around in the scene, telling jokes and encourage the user to color the barn. Every now and then, they tell the children to drink their milk and eat their food. The app combines the important start of the day in a family setting with a healthy product with a fun and a potential social game. In addition to developing a concept that builds on an existing brand story world, Baumann Larsen believes there are three distinct features that should be included when developing a story based AR app. Each of these features will make the most out of the media and make for a more immersive and engaging augmented experience for the user:

1. Include the marker and the physical room into the story. In the first Tine app, the animated cows interact with the milk carton (the marker) by reading from it and by talking in the same local dialect in Norway as the area in which the milk carton was produced.

2. The location of the user (device) is inherent to AR, so one should create a visual connection between the virtual world and the user. In the case of the Tine Kuer AR app, the cows would look around and talk to the user to ask for help in the coloring of the scene, including the user into the story.

3. Enable user interaction with the scene. In the first TineMelk AR app, the user could only poke the cows, and they would react to it by replying with one-liners. In the last app, the interaction was a complete 3D coloring game.

## 5.2 Cartoony vs Photorealistic 3D Graphics

When designing 3D content for AR, the designers must choose a visual style for the virtual scene. Should the virtual scene be graphically stylized/cartoony or as photorealistic as possible? The examples in the research papers on lighting have a clear goal of developing techniques for a direction towards a photorealistic illumination of the virtual scene, something which is a difficult task, if even possible, at the current state of mobile graphics.

In the process of transferring the concept from TV to AR, the developers of the Tine app ended up with a style they call stylized realism. This means basically that the scene have a bit of both where it ends up somewhere in the middle but not photorealistic. Baumann Larsen argues that going away from the photorealistic towards a cartoony style, actually makes it more believable. The illusion breaks since it is more apparently “wrong” when something pretending to be photorealistic doesn’t succeed 100%. When some elements in a scene are photorealistic, users would, to a larger degree, have higher expectations because one knows the notion of reality so well. An overly cartoony style would break too much with reality for the users to be able to accept it for what it is since one of the goals of AR is to seamlessly blend the digital scene with the physical world.

Baumann Larsen explains further that in the case of the apps made for Tine, instead of going for a complete realism, the developers lit the scene primarily with a dome light. This means that the main light is coming from a hemispherical dome illuminating the scene from all directions. A soft key light was added to give the 3d scene more form. This produces subtle contact shadows between the objects in the scene and there is no apparent direction in light/shadows. This makes the scene functional from all directions in an AR app. Materials and textures were baked in to single unlit materials where all the light information is stored in the textures. This is to keep the shaders simple and effective when it comes to hardware demands. From an industrial point of view, this was meant to work on as many smartphones and tablets as possible. This is a huge challenge, especially on the Android platform, since there are a large number of different types of devices. To further integrate the AR scene with the physical reality, an organically formed alpha map was used for the edge of the scene.

Based on the industry best practice experiences from Placebo Effects and Labrat, both the method of lighting with dome lights, simple materials (bake all information into one unlit map) and the choice to encourage the students to go for a more cartoony graphical style was included into the course.

## 6 Results and Discussion

The first time the course was conducted, the last assignment contained figure animation. Since the course in 3D animation went parallel to the AR course, they had to learn animation simultaneously. Figure animation is complicated and potentially quite time consuming. Extra lessons on animation were provided in order to help out. The result was that the students used a significant amount of time on animating and learning to animate. The produced apps would typically have nice graphics, based on the lighting methods described, but the apps would only contain the scene, sound and an animated figure placed on the image tracker. There would be no interaction or other elements to strengthen the experience. In the evaluation of the course, the students also had, only to some degree, tried to have a coherency between all the parts of the assignments. For example, in some cases they would have one style in the design of the marker that didn't necessarily connect to the scene visually.

Based on those experiences, the next time the course was conducted there was a more theoretical focus on coherency and on adaption of existing style. A lucky issue that had an impact on the structure of the course was that the 3D animation course was moved to earlier in the education, so the students who elected to take the 3D design for AR course already had learned animation. This freed time to use on other elements.

The animation in the AR course would instead have a focus on making animated behavior loops that could be reused, which was more time efficient. Another element that was taken into the course was a bit of scripting for interaction. 3D graphic students are by nature not the most adept programmers, so this was just a very basic C# intro, with some simple trigger scripts. The students were then encouraged to make intros for their scenes. This, combined with trigger scripts, would make a way of manifesting the Virtual Reality in the Real Reality by some simple interaction. This could be as simple as using a start button to start the animation of the 3D content to more advanced scripting features. The teaching of lights and shadows was also developed to include a technique to make a connection between the virtual and the real by making alpha maps with subtle contact shadows.

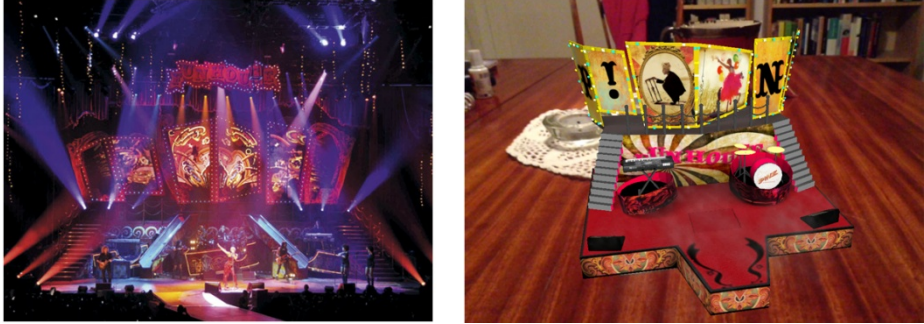
Finally it was also focused on designing splash screens and icons for the app in order to have complete product from start to end.

The results of the assignments after the second time the course was completed was overall significantly better in terms of graphics, coherency and overall total experience. The interaction - even in the cases when it was very simple makes the viewer engage in the app. Some of the students used the scripting more than others depending on their skills with programming. In one case a student made it possible to trigger fireworks on the stage by touching it. Another student made a Stevie Wonder concept, scripted with a graphical equalizer as a scene element, which moved according to the music [III.4]. It also included loudspeakers in the scene that were controlled by a script to trigger the bass elements in time with the music.

One good example on scene adaptation is one of the student works featuring the artist Pink where the scenery from the artists "Funhouse" show was used as inspiration [III.3]. The design process of the tour was already well documented on the artist's webpage, with photographs from the actual show and 3D renderings from the

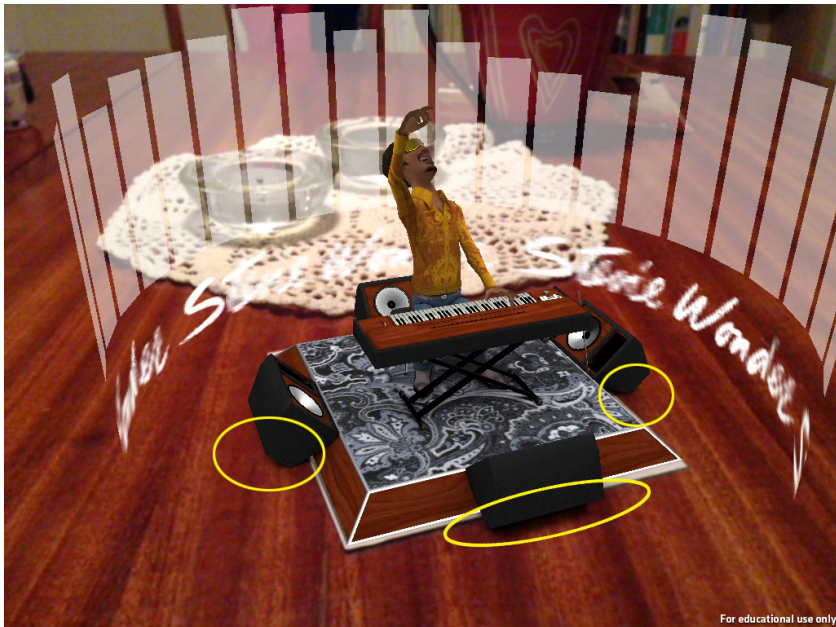


planning of the stage design. The student adopted the design of the scene with clear elements from the original, with the circuslike forms, the panels back on the stage and in the use colors, concept and design from the real show. An animated Pink figure would appear by poking a little hatch on the scene floor.



**Fig. 3.** On the left: The original designs of the funhouse show [16]. Right: AR funhouse designed by Kine Marie Sæternes 2013.

The illustrations [3 and 4] also show the effect with the dome lighting that produces soft contact shadows and space in the virtual scenes. This makes uniform lighting that can be viewed with the same quality from all directions of the scene. With static,



**Fig. 4.** Stevie Wonder AR app by Philip Stevju Løken 2013. Scene with subtle contact shadows with alpha channel and scene with scripted equalizer and bass elements.

sharp shadows as described by Sugano, Kato and Tachibana [9], it may enhance the scene compared to not having shadows at all, but it might also be perceived as disturbing if it breaks too much with the physical lighting of the camera image. As seen in the Stevie Wonder concept [III.4], soft and subtle shadows rendered to alpha maps make the virtual scene connect to the surface it is projected to.

So far a cartoony/stylized representation seems to visually work for AR in many cases. However the intensive research on AR, computer graphics in general and hardware enhancements makes a future hope of photorealistic virtual content for AR likely.

## 7 Conclusion and Further Development

The overall technical goal of making AR apps is to have a believable blending between the real and the virtual, but the human factor is about content and what to present. The course was designed with experiences from the industry, which makes a high demands from their customers. Bringing in the industrial side of the production makes a focus on completeness and coherency. Although the apps produced by the students have a simple and limited narrative focus, it seems that focusing on coherency in the design and completeness seemed to enhance the quality of the products the students made.

The introduction of scripting had significant value where it brought interaction as an element into the work.

The fact that the students had a year with experience with 3D graphics and especially that they could do some figure animation before the course started made them more capable of doing a fun and interesting story.

Further development of the course would enhance the conceptual side in the planning in order to have more consistent stories. More scripting could also be considered, enabling even more interaction from the user into the virtual scene.

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