Project2 Documentation

An introduction into Augmented Reality

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Abstract

The goal of this project2 work is to create a proof of concept in preparation for the Bachelor thesis, which will start in the next semester. The ultimate goal of the Bachelor thesis is to create a prototype for displaying/animating tubes and cables of walls from buildings on your smart phone or with a laser projector. With this technology, we give the user an opportunity to simulate an X-ray like experience to see trough walls. The goal of this work is to understand what augmented/virtual reality is, how it works and eventually to evaluate the possibilities of it. A fundamental knowledge of available technologies on the market and also the evaluation which one fits the best for this kind of project is an objective of this work.

After diving into the topic, we realized that the state of the art in Augmented/virtual reality is not advanced enough for our ultimate goal. There are some interesting aproaches, which possibly can fullfill the needs for this work in near future. Because of that, we decided to check out what the capabilites are nowadays and what one can do with them.

Versions

Version	Date	Status	Remarks
0.1	11.11.2017	Draft	Initial draft of the document
0.2	11.11.2017	In Progress	Ready for revision
1.0	18.01.2018	Final	Final version

Contents

1 Introduction

Considered to be one of the most defining technologies of modern computer technology, augmented reality (AR) provides a real time direct or indirect view of the real-world environment and then "augments" this view virtual components. Augmented and cirtual reality is rapidly gaining importance in modern information technology. Right now, it is mainly used for gaming experience and advertisement.Ikea for instance, created an augmented reality application to animate and display furniture on a fixed place in the room on your smart phone through the camera to give the user a virtual representation, how the furniture looks like. Although this was only for commercial purposes, it shows what augmented reality is already capable of. Another well knows example is the augmentation in sports. In tennis, the review will be augmented in order to see, were the ball landed exactly. Or during football games, one can display the offside line with AR. Of course, these are very basic usages of Augmented reality. With rapidly increasing possibilities, this technology can help humanity in everyday life.

An opportunity to simply "scan" walls inside buildings with your smart-phone or the possibility of real-time projecting the animation directly on the subject, can create a new field for Augmented reality. With Applications who can help in everyday life, augmented reality will be taken more serious in the Computer Science field.

The goal of this work is on a first step to understand what augmented/virtual reality is and how it works. The second objective is to get a glimpse into the technologies available on the market, what the possibilities of these are and eventually, which one fits the best for the bachelor thesis.

2 State of the Art

In 2017, augmented reality is still cutting edge technology. Apple is working on ARKit for IOS devices(Iphone 6S and newer) and Google just released a preview version of ARCore(Samsung S8 and Google Pixel). Both are SDK's for generating augmented reality. Although the ARKit release was in summer 2017, there are already several apps available and developers are able to work with it. ARCore on the other hand is still in preview. An exact release date has not been communicated at the moment from Google. Android developers can work with Project Tango. Project Tango is somewhat like the predecessor of ARCore but has been suspended a few months ago. Another issue is the fact, that one need special hardware in order to develop Tango applications.
Vuforia & unity is the third well known option to generate AR applications. Since Unity version 2017.02, Vuforia can be programmed out of the box. A big plus is (conditional) platform independence. Vuforia & Unity applications run on any newer mobile device. A standard for web applications is not available at the moment.
Overall it stands out, that augmented reality generates a great interest for big companies like Google and Apple. The market of augmented reality technologies is changing extremely fast. Right now, no one can predict which company will take the lead and which technologies will prevail in this field. But it is most likely that augmented reality won't go away anymore. It seems that Apple is technological advanced with ARKit in comparison to ARCore. But both competitors working actively on AR. No one can say when augmented reality will take place in our everyday life, but with new technologies, there are new possibilities.

2.1 Available AR Technologies

Like already mentioned, there are a lot of technologies on the market, which can be used for augmented reality. For this project it is important to divide these technologies in native apps and non native (browser) since a platform independence is desired.

2.1.1 Native

Native applications are in general faster and one has more control.

OpenCV *"is a well known Library for Augmented reality. It has C++, Python and Java interfaces and supports Windows, Mac and Linux. OpenCV was designed for computational efficiency and with a strong focus on real-time applications."* [3] The API includes different algorithms like recognizing faces, track moving objects, follow eye movements and many more.

Project Tango is a new project from Google. It takes augmented reality and especially tracking and environmental understanding on a new level. One needs to buy proper hardware to run Tango apps since it needs a special camera which allows depth measurements. With this hardware, it is possible to evaluate the relative position to the environment without using GPS or other signal based location technologies. It has a C++ and a Java interface. In August 2017, Google announced, that Project Tango will be replaced with the augmented reality platform ARCore, since ARCore does not require special hardware in the way Project Tango did.

ARCore ARCore is an SDK for creating augmented reality apps on Android. It uses one the one hand motion tracking to track its position relative to the world and on the other, there is environment understanding. Environment understating allows the the hardware to detect the size and location of (flat & horizontal) surfaces. Right now, there are only three devices, which can run ARCore applications (all of them have the Android Operating System). Plus it is only being offered in an early preview version and is considered as bleeding edge at the moment. A big plus is the choice of the development platform. ARCore offers to work with Android Studio, Unity or Unreal.

Unity & Vuforia Unity 2017.2 integrates the Vuforia engine. Vuforia is a software plattform for creating augmented reality apps. The platform supports Android, IOS and UWP devices. It is self-explanatory, that one can only develop for one Operating system at a time. According to the website, it is the most widely used platform for AR development. One does has no need to work with AR codes for tracking. There is a possibility to create your own tracking medium. There is a possibility too, to work with object tracking. The support and community seems far advanced, comparised to other AR solutions.

2.1.2 Browser

Browser applications on the other hand have a better accessibility since you don't need to install anything. Although there is no standard for creating augmented reality applications in browsers, since it is still edge cutting technology right now, there are possibilities to start experimenting.

There are different libraries and frameworks to work with.

AR.js is one of them. It is fully written in JavaScript and uses three.js and jsarToolkit5. It is really fast and even works on older phones. Since the AR.js project is only in the beginning, the community is small. At the moment, there are only examples with AR tracking to find.

XZIMG can be run entirely on browser too. The focus is on face recognition. There is a free trial version of it, but to develop you have to buy the professional version.

Awe.js runs entirely on JavaScript and can be run on every browser. Awe.js has an option to real-time interact with the projected objects. It has a free trial version, but if one wants to develop, he has to pay monthly.

Unity Web has it's own browser to run applications in it. With unity, one has the opportunity to develop augmented reality in a far advanced game engine. The focus of unity is in game development. Nevertheless, there are good examples for augmented reality. But the browser from unity is no longer supported. Which means one has to work with the current version.

2.2 Conclusion

In the beginning of this project, Dr.Prof.Reto Koenig mentioned, that a web-app is desirable but not mandatory. Because of that, the focus was on web technologies. Nevertheless, also native technologies has been tested. After developing a first application with AR.js(a 3D cube, which turns around it's own axis on a Hiro tag), we were satisfied with the result. The camera had troubles finding the tag in some cases like bad light or smaller angles. Another application has been developed with Unity and Vuforia. The result, compared to the previous application was surprisingly good. The rendering was smoother and also light and angle seems not to matter with this technology. To get a third opinion, Dr.Marcus Hudritsch has been consulted. Dr.Marcus Hudritsch works actively with virtual reality and augmented reality and is also in charge of different projects of this kind right now. His statement was clear. Web technologies are not sufficient for this kind of task. He highly recommended ARCore or ARKit for a project like this. But Dr.Marcus Hudritsch also mentioned, that ARCore is bleeding edge at this moment.

3 Preliminaries

Since the augmented / virtual reality field is still young and rapidly growing, there are a lot of technologies available on the market. Before we can decide which one fits the best, we'll need a better understanding of what we actually need.

Virtual reality *"is an artificial environment that is created with software and presented to the user in such a way that the user suspends belief and accepts it as a real environment. On a computer, virtual reality is primarily experienced through two of the five senses: sight and sound."* [6]

Augmented reality *"is a live direct or indirect 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."* [5]

The Interaction with the real-world environment is basal for the ultimate goal of this project since we want to "augment" this environment with additional 2D/3d Objects. Because of that, augmented reality is the right direction. It is important to understand that in Virtual Reality, it is not important if one moves the scenery relative around the point of view(eye), or vice versa. In augmented reality it is essentially to know, that this is different.

3.1 Augmented reality

3.1.1 Application fields

In theory, AR can help in various fields:

As help for complex Tasks AR creates the possibility to display additional Information in complex tasks. For instance an X-ray image could be rendered and directly displayed on the real world fracture.

For navigation AR can manage navigation in different fields. BMW for instance, already uses a static approach of augmented reality in new models, were the navigation is displayed on the front window of the vehicle. But also a usage to navigate soldiers through battle zones is imaginable.

Entertainment Right now, AR is mostly used for entertainment purposes. The most famous example is the smartphone game Pokemon-Go. The application used GEO Tracking to evaluate where the user is in the real world and augmented Pokemon's inside the environment. But The level of interaction is fairly simple.

3.1.2 Technology

The next question is if augmented reality can fulfill our needs for this project. In order to decide that, we need to take a closer look at AR.
Basically, augmented reality consists of four main components:

- The camera is needed since one needs a stream or a video of the real world environment.
- One wants to project/animate something in this real world environment and thus an object is needed.
- One needs tracking to find out, where the object should be displayed in the real world environment.

There are different possibilities to handle tracking, visible in the following figure 3.1.

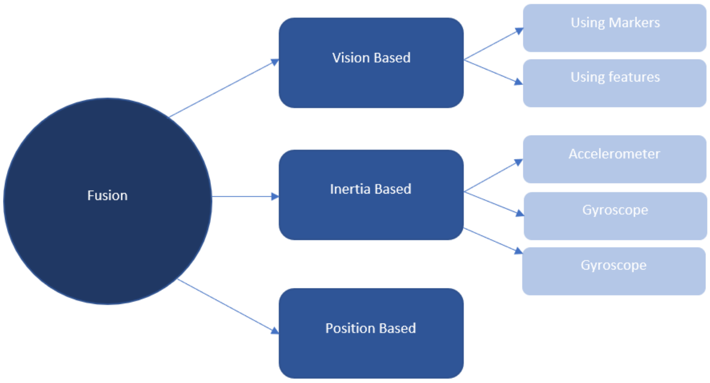

Figure 3.1: Tracking methods

Vision Based

Using markers is the most straight forward approach to evaluate where the animated object should be displayed, is using markers. Foregoing it is necessary to understand the term "marker". The goal of a marker is fairly simple. Markers are distinguishable elements put in the real world environment so that they can be identified apart from other objects. Markers can be categorized into active and passive markers. Active markers emit a signal(magnetic waves), which can be received from the sensor. Passive markers on the other hand, tend to be a pattern which can be isolated from the texture of the environment. Reading QR codes is a well known example for this. If one works with passive markers, it is necessary to apply computer vision methods for recognizing the image/pattern.

By using features(markerless) the application does not need any preknowledge of a users's environment to "augment" objects into the real world environment. While marker-based methods use specific active/passive markers, markerless positional does not require them, making it a more flexible method. Markerless tracking only uses what the sensors can observe in the environment to calculate the position and orientation of the camera. I.e. The feature method depends on "natural features" instead of specific markers. Explaining how feature detection works in detail would go beyond the scope of this documentation. Nevertheless it is important to understand how feature detection basically works to reconstruct how markerless tracking works. A feature is a point of interest in an image, distinctive to others. To detect these feature points is not as easy as one might think. Sophisticated and expensive(a lot of operations needed) computer vision algorithms are used to evaluate this points. A famous and frequently used algorithm to find feature points is the SIFT(Scale-Invariant Feature Transform) algorithm.
For instance the edges of a yellow carpet laying on a black ground would create a feature, since it has a high frequency(yellow to black). As one can imagine, the higher the frequencies of an image, the more features will be detected. In theory, features should be re-observable from different point of views under various lighting conditions. So if the edges of the carpet are once saved as feature points, they will be also recognized from other ankles. Thanks to that, it is possible to gain an understanding of how the image/view is built.

Inertia Based(IMU)

Smartphones nowadays all have an IMU (Inertial Measurement Unit) inside the hardware. The IMU is a spatial combination of different inertial sensors like the acceloremeter, the gyroscope and the magnetometer. Thanks to the IMU, it is possible to calculate the changing of the position of the hardware relative to the space. To gain accuracy of this calcualation, a so called Kalman Filter wikipedia.org[1] is used. How this filter works in detail is complex and will not be explained in this document. For the understanding of the usage in augmented reality it is necessary to know that it is used to minimize errors of readings from the different parts of the IMU.

[1] https://de.wikipedia.org/wiki/Kalman-Filter

An accelerometer is a sensor, which measures the acceleration of itself. This is achieved with respect to the inertial force. Thanks to that, the accelerometer can distinguish between speed increase and speed decrease. Furthermore it is important to understand that the accelormeter can measure acceleration in the 3D space, shown in figure 3.2.

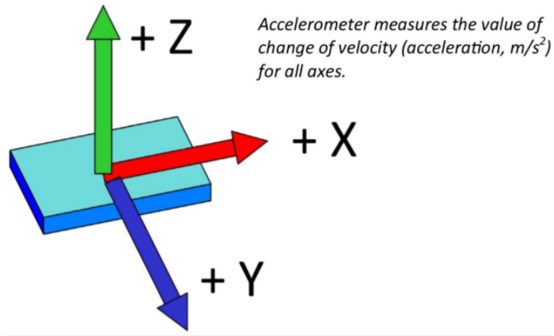

Figure 3.2: Accelerometer [4]

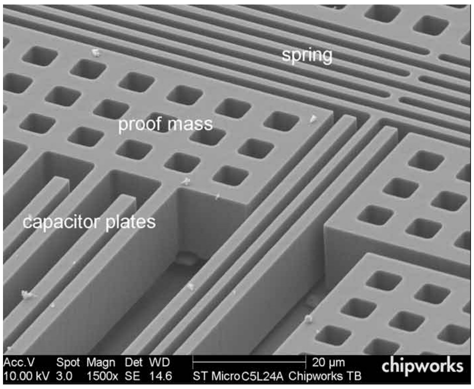

Figure 3.3: Accelorémeter under a Microscope [1]

Gyroscopes *"measure angular velocity, how fast something is spinning about an axis. If one is trying to monitor the orientation of an object in motion, an accelerometer may not give you enough information to know exactly how it is oriented."* [4]

The magnetometer *"sensor in your tablet or smartphone also utilizes the modern solid state technology to create a miniature Hall-effect sensor that detects the Earth's magnetic field along three perpendicular axes X, Y and Z. The Hall-effect sensor produces voltage which is proportional to the strength and polarity of the magnetic field along the axis each sensor is directed. The sensed voltage is converted to digital signal representing the magnetic field intensity."* [2]

Position Based

GPS (Global Positioning System) is another approach for markerless tracking. The difference is, that there is no need for feature detection with this technology. The 3D objects are positioned dependent on the geological position of the hardware. The relative position to the hardware is calculated with the GPS coordinates and tracking of the motions. However, it is important to understand that a lot of of indoor environments like laboratories or buildings generally block these signals. The uncertainty of GPS signal in the indoor environment calls for more reliance on vision-based tracking systems. Most AR frameworks don't support GPS tracking because, even outdoors, the accuracy is not sufficient in most cases.

Fusion

Considering the two new emerged frameworks to develop AR, ARKit and ARCore, one has to know that these technologies work with a fusion of these tracking possibilities. ARcore for instance uses a process called concurrent odometry and mapping(COM), to understand where the phone is relative to the real world environment. ARcore uses feature point detection too, and computes with these points the changes in location. This information is combined with the inertial measurements of the IMU to estimate the position and orientation of the hardware relative to the real world environment in real time.

But ARcore goes even further by implementing "environmental understanding". The goal is to clustering feature points together, who appear to lie on common horizontal surfaces like tables or desks.

During development of the first ARcore application, we realized, that the augmented 3D objects, which were added to the real world environment, were not as stable as seen in presentations of Google. We used a Google Pixel XL in order to run the first application. After cooperation with another team who also works with ARCore, we realized, that the same application runs more stable on a Samsung galaxy S8. With this information, we wanted to find out, why the same application behaves differently on the two smartphones. Because of that, we measured the readings from the accelormeter of different smartphones including the Samsung Galaxy S8 and the Google Pixel XL, and calculated the standard deviation of the measure results.

4 Results & Discussion

4.1 Results of measurements

For the test, we went into an empty lecture hall and covered a flat surface with a textile piece. Then we located each smartphone on it and started to measure the accelerometer datas for two minutes. Below, one can see the results in form of a gauss bell below for the Google Pixel XL in figure 4.1 and the Samsung Galaxy S8 in figure 4.2.

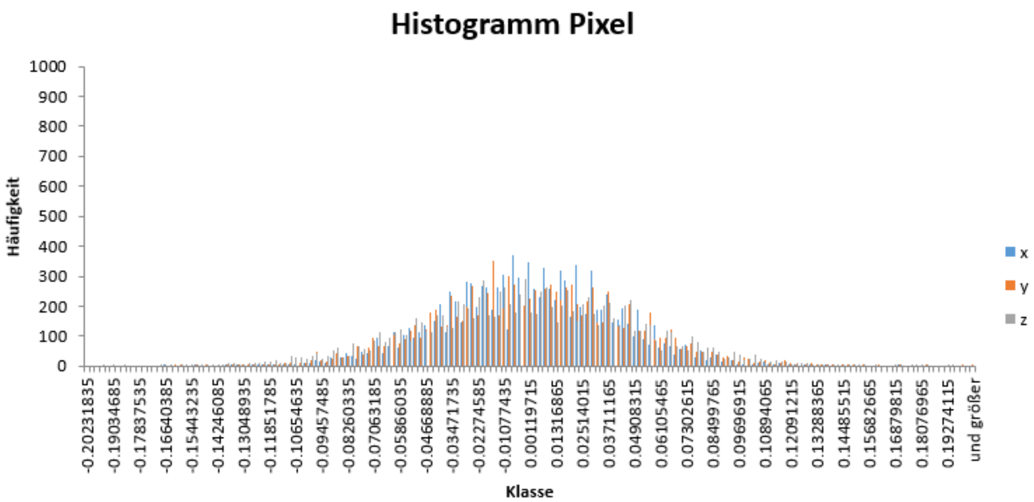

Figure 4.1: Standard deviation under a gauss bell from Google Pixel XL

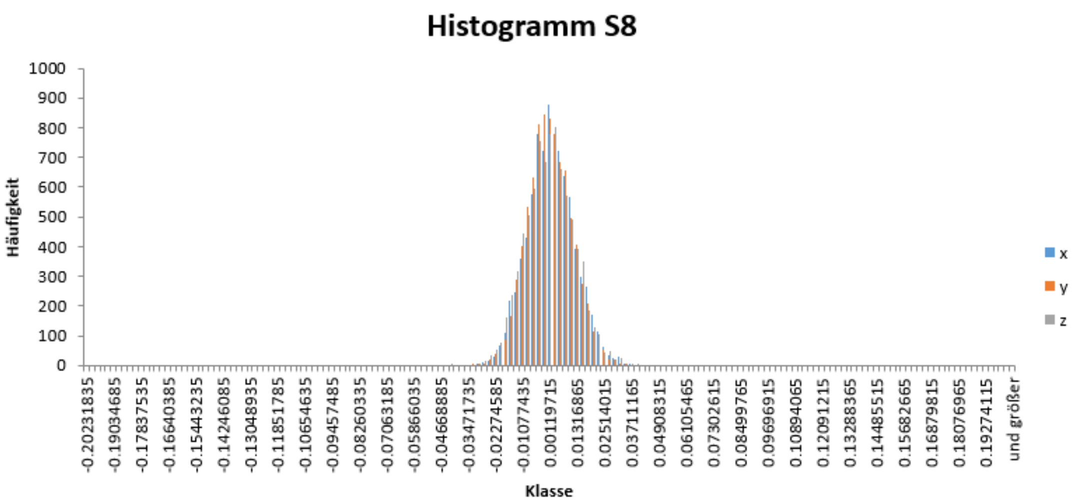

Figure 4.2: Standard deviation under a gauss bell from Samsung Galaxy S8

As one can see, the Google Pixel has a greater standard deviation of approximately factor 4. We conclude that the quality difference of the same application run on these two smartphones is caused by the accelormeter datas.

4.2 Libraries / APIs

4.2.1 WebGL

The very first approach to dive into augmented reality was to understand, what WebGL is and how it works. This decision was made in the early beginnings of this project since a web application was desirable. After writing some code and analyzed the output of it, we came to the conclusion, that WebGL is not the right approach for our goal. With this technology, one works on a low level and has a wide variety of configuring things. However, the effort to even create small things is too big in this case. The code written for this validation with explaining can be found under github.com[1].

Figure 4.3: WebGL primitives

4.2.2 Three.js

Three.js is a JavaScript 3D library. It is used for creating 3D objects and animations inside a browser. AR.js uses three.js for creating the object, which is desired to display in the real world. Because of that, it is fundamental to understand how three.js works in order to work with AR.js. For preparation purposes and to evaluate what the possibilities with three.js are, a basic Shape has been programmed. The code can be found under github.com[2].

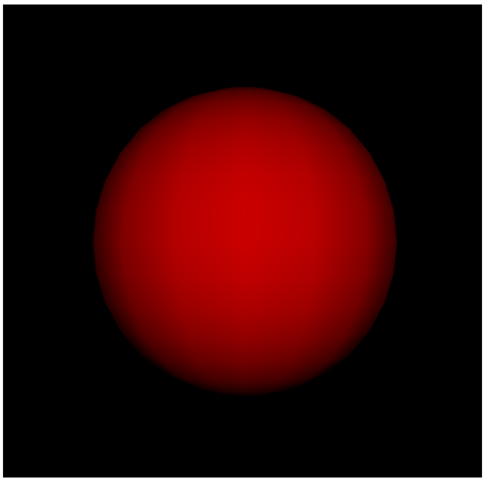

Figure 4.4: Three.js Object with phong shader.

[1] `https://github.com/nydej2/webGLHelloWorld`
[2] `https://github.com/nydej2/Project2`

4.2.3 AR.js

Another Web based approach was to work with AR.js. One works with a higher abstraction level and it is speicalized for augmented reality applications. To run a first application is fairly simple. Since it is all written in Javascript, one only has to download the github repository from AR.js and simply run the sample applications in the desired browser. However, the animated objects are created with three.js. The AR.js Library can be downloaded under the following link github.com[3]. A written sample of a three.js object can be found github.com[4].

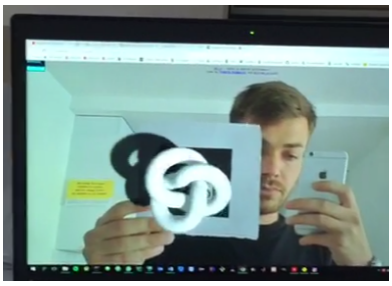

Figure 4.5: AR.js approach

4.2.4 Unity & Vuforia

A native approach for augmented reality has been tested with Unity & Vuforia. We worked with a marker detection too in order to augment something into the real world environment. Thanks to the well developped Unity engine, it was more straightforward to implement the animated objects. Furthermore the application runned smoother and more precise compared to web approaches.

Figure 4.6: Unity Vuforia approach

[3] https://github.com/jeromeetienne/AR.js/blob/master/README.md
[4] https://github.com/nydej2/Project2

4.2.5 ARCore

Another native approach is ARCore. As one can read, this technology is in development by Google and can only be download as a preview right now. Nevertheless, one can see the possibilities of ARCore already. Since ARCore works with feature points and inertia based measurement, one does not need a specific marker. nevertheless, during working with this technology, we realized that it is compellingly to work with surfaces, which hold a certain amount of feature points. ARCore will not recognize a plain surface. Because of that, we added some feature points to our testing environment.

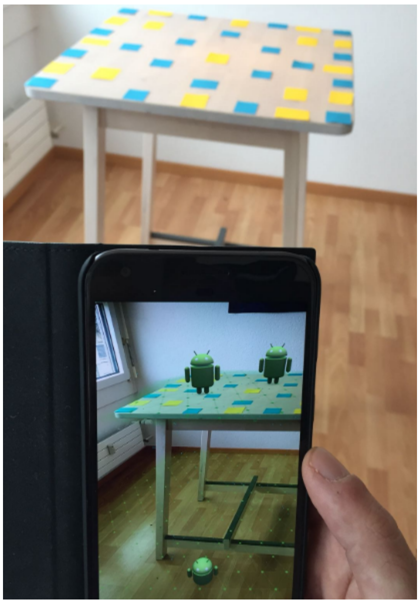

Figure 4.7: ARCore approach

4.3 Conclusion

Augmented reality is a technology, which is still in early development. The possibilites to develop proper AR applications are limited. During this project, Prof.Dr.Reto Koenig and I realized that our idea of our ultimate goal is not achievable at the moment. Prof.Dr.Marcus Hudritsch confirmed our assumptions. But augmented reality is emerging and there are good chances that in near future, one can see this technology in every day life. With the knowledge of this work, we decided to evaluate the possibilites of ARCore in the bachelor thesis.

Declaration of primary authorship

I hereby confirm that I have written this thesis independently and without using other sources and resources than those specified in the bibliography. All text passages which were not written by me are marked as quotations and provided with the exact indication of its origin.

Place, Date:	Biel, 18.01.2018
Last Name/s, First Name/s:	Jonas Nydegger
Signature/s:	....

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List of Figures