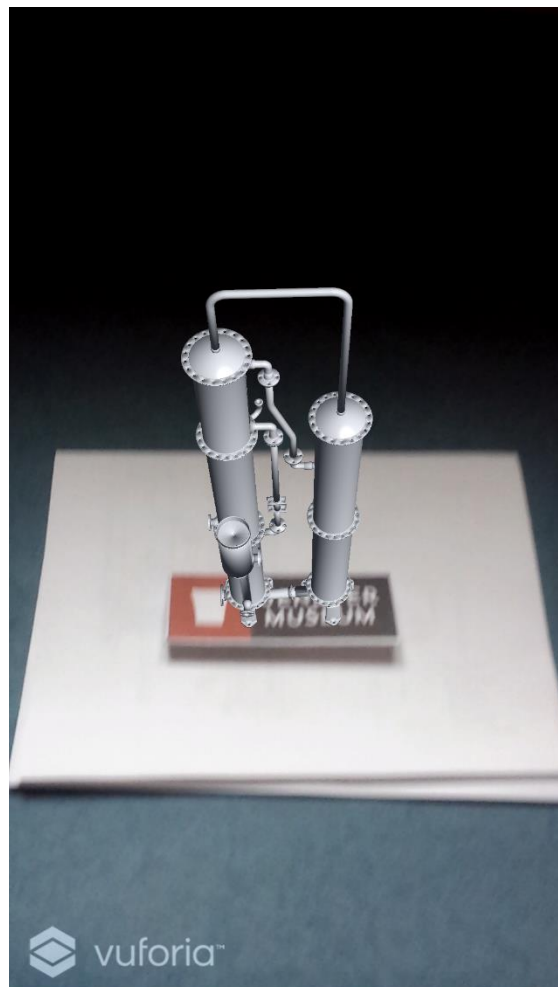# Augmented Reality based on markers: explaining a distillation column

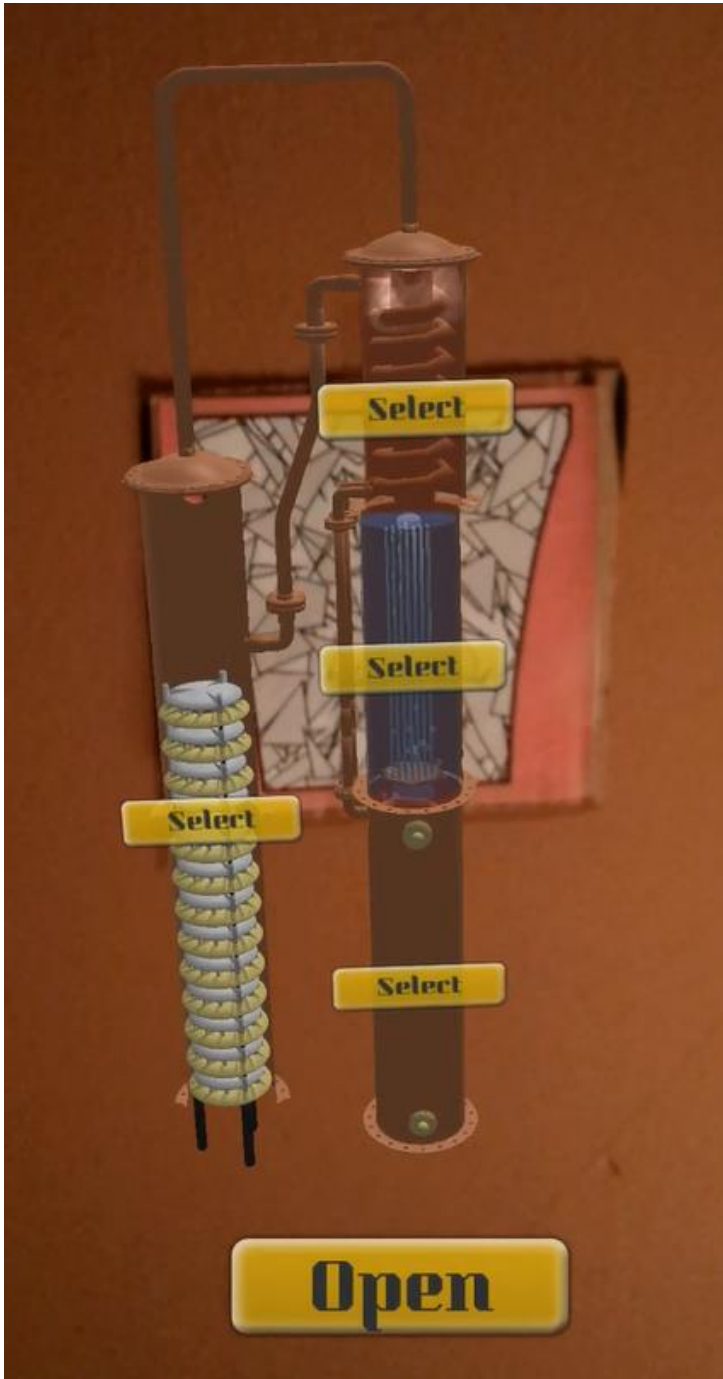Vermeulen Igor

Digital Arts & Entertainment

Content

1.Introduction

I'm Igor Vermeulen, a student at Howest. I'm writing this paper as a result of research I performed for my graduation project. My graduation project consists of creating an augmented reality application for the "Jenevermuseum". The application's function is to help in the explanation of a distillation column through a very visual and interactive augmented reality experience.

In this paper I will explain the steps I took to find the best way to create an informative and fun augmented reality experience. More details about the project itself and what problems it gave, as well as how I thought of a solution for them, will be discussed.

2.Project details

In my first meeting with my mentor, Michiel Houwen, I got to talk to Tine Verroken. She is the project coordinator that got in contact with our school for this project. She explained me that the museum in Hasselt, the "Jenevermuseum", had a case where they were looking for a way to help them explain the process of one of their distillation columns. She told me that it is very hard for the visitors to understand how the distillation column works because you mainly see two big cylinders. These are connected with tubes and pipes that show some meters. But the actual process happens inside. This led to the conclusion that with the help of augmented reality it could be easier to understand what happens inside. She gave me the contact details of Joanie Dehullu. She is the collection manager of the museum. Tine also provided me with CAD models made by students from a different school and a short video explaining how the distillation column functions.

I went to the museum to see the distillation column. Joanie provided me with more explanation of how the museum functions and how she sees the application work within the museum. They mainly want it to function for mobile devices, tablets are less important. This is because visitors come here on their own and they didn't like a system where one could borrow a tablet from the museum. If it works well they do want to have a tablet that rune the application. This is for when groups/schools come and ask for a guide. The guide will then use this tablet to explain and show how it works. But as this does not happen often, they mainly wanted it to work for the general visitors on their phone.

Something else I noticed during my visit is that the distillation column is very big and the room is relatively dark. This might give problems for tracking. The distillation column still gets used so putting markers on the column itself was not allowed. I will get into detail on this later.

To sum it up quickly, what they expect is:

- Easily accessible for visitors on their **phone**
- **Clear explanation** of how distillation works
- Make it **visually** attractive to look at
- Try to get it **universal**, meaning everyone in the world can use it

How I will approach this was completely up to me.

3.Augmented Reality based on markers

What is augmented reality?

Augmented reality augments the view that is seen through a device (camera). The device modifies the reality with use of computer-generated sensory input, such as sound, images, video or GPS data. In contrast to virtual reality where a whole other world is simulated to replace the real world, augmented reality will change the real world in real-time. Basically augmented reality brings the digital world in overlay with the real world.

There are multiple ways to get an augmented reality experience. Most are still in development but to name some:

- **Hololens**[1]: A device you have to wear on your head that shows augmented reality on a semitransparent holographic lens.
- **Head-up Display**: Augmented reality HUD gives the user extra information about their environment. E.g. in cars[2]
- **Contact lenses**[3]: These are still in development but the main idea is to get bionic contact lenses to enhance and manipulate what the user sees.
- **Mobile**: Probably the most known way to get augmented reality. The camera on the phone percepts the reality, and based on this it is able to add augmentations.
- …

Evidently for this project I will focus on mobile augmented reality.

There are quite a few developers out there already that have already made a successful application using this technology for mobile devices. The applications utility can vary from begin used in games, to commercial use and to help in the job environment. Use your imagination and you will find that it can be used nearly anywhere.

A quick example for a game would be the now popular **Pokémon Go** app. This app puts Pokémon in the real world. The technology used here relies mostly on your gps system and your phones motion sensor(s).

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[1] https://www.microsoft.com/microsoft-hololens/en-us
[2] http://continental-head-up-display.com/
[3] https://www.cnet.com/news/augmented-reality-contact-lenses-to-be-human-ready-at-ces/

Another cool app that can demonstrate the power for commercial use is **TryLive Home by Total Immersion**. This application previews furniture in your home, which makes it easier for the user to try new furniture that fits their style. It makes shopping a lot easier as you can see the end result immediately. This app uses a marker as target and uses that to spawn 3D furniture.

For the job industry AR can provide an accurate explanation to solve an issue. In other words: **Visual repair instructions**. For example an electrician could see which wires should be connected where. The technology here relies on 3D scanning (to recognize different components) and project the solution using that.

How does it work?

There are 2 ways to accomplish augmented reality for mobile devices (at this moment).

The first one is based on functions that exist on your phone to determine your position. GPS, velocity, pedometer, internet connection, … take a huge part in this. This is so called markerless augmented reality and it is very dependent of the capabilities of your phone. It is also limited in accuracy as GPS tend to have a small inaccuracy of a few meters.

The second method is based on markers. This method utilizes an image/3Dobject as target. The device knows what the marker looks like and tries to find it in the camera display. If a marker is found that corresponds with the image/3Dobject that needs to be tracked, the device can project the augmentation on the right place.

Developing for marker-based augmented reality

There are a ton of SDKs out there for developers to use. The main process for developers is to register an image that needs to be tracked, then place that image in a virtual scene. Based on the position of that marker in your scene you can place 3D objects or other elements. In augmented reality these will have the same positions and rotation relative to that marker image as you had put them in that virtual scene.

4.Tools

Unity as work environment

I wanted an environment that I was familiar with in developing. That's why I choose to use Unity. Unity is mainly used for games, but many SDKs made their kit Unity-compatible as Unity is very user-friendly to work in. It would also help me speed up the process of creating a stable and easy to use application as I am very familiar with how Unity works. This will also ensure I can deliver a high standard product in the limited amount of time I am given.

Choosing the right Software Development Kit (SDK)

Like I mentioned there are a ton of SDKs out there, luckily I found a website[4] that listed very nicely a bunch of SDK's and compared them with each other. As I really wanted to use Unity a lot of these SDKs were filtered out because they weren't compatible.

Secondly I thought it would be optimal if the SDK was free to use for prototyping, with the ability to go on a commercial option later on (best would be to stay free of course).

After quickly comparing the possibly SDKs I found 3 that seemed perfect to use. Vuforia, ARToolkit and Kudan.

I tried Vuforia first as my mentor also recommended this one the most. The setup was relatively easy to get. Then I tested if it was easy to get something small to work. In less than an hour I had my CAD model showing on top of a marker through an app on my phone with a custom marker. I also liked that there was a lot of documentation and extra tips on the Vuforia website to help developing.

Next one was ARToolkit. This didn't go as well as I had hoped it would. The setup worked fine, but if you wanted to create a custom marker you had to do a lot of additional steps. Whereas in Vuforia you can upload a custom marker image and download the dataset, here you would have to train ARToolkit to recognize your custom marker, calibrate it and creating new files. It definitely slowed down the process considerably. I also keep in mind that I most likely need to use multiple markers, and thus calibrating every marker separately would slow down things a lot.

As last one I tested Kudan. After installing their plugin for Unity it asked for a bundle code. The code was nowhere to be found. There was almost no information about Kudan by other developers and their website didn't provide much help either.

This concluded for me that Vuforia would be the best option. It felt relatively easy to work with, their website has tons of information. By far I think Vuforia is the optimal augmented reality SDK to use for this project. Vuforia is free for prototyping, there is an option to buy it for commercial use.

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[4] http://socialcompare.com/en/comparison/augmented-reality-sdks

Using vuforia

Vuforia is really simple. You make an account. Go to your develop. First you will need a license so just add a license in the license manager. Next you can create a Database. This is in the Target Manager tab (still under Develop tab). A database is a collection of markers. So after creating a database you can upload an image using the Add Target button. This will be the marker you will use.
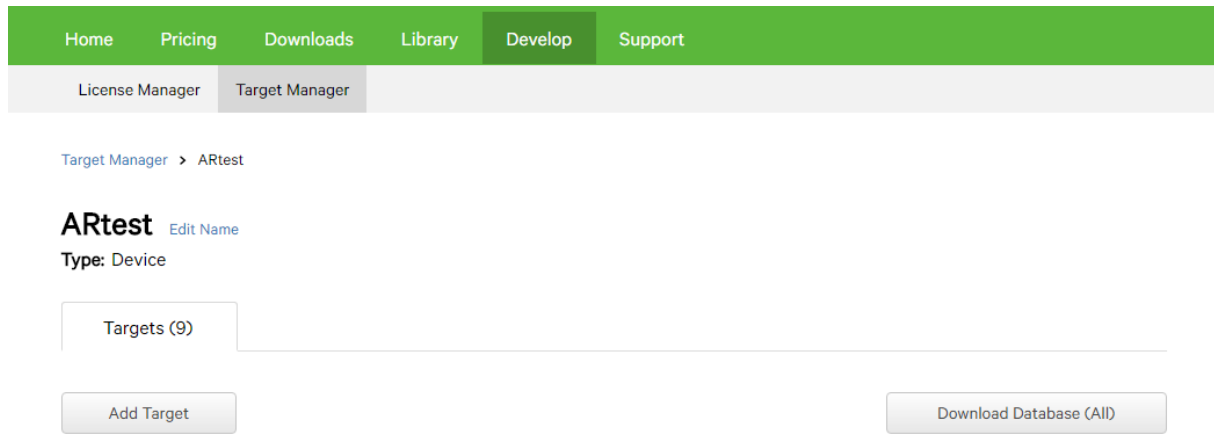

After you've done that you can download your database and choose the unity package. You can just drag and drop this package in your unity project.

In the unity project you will have a bunch of prefabs. You will need an ARcamera and put the app license key in the behaviour script
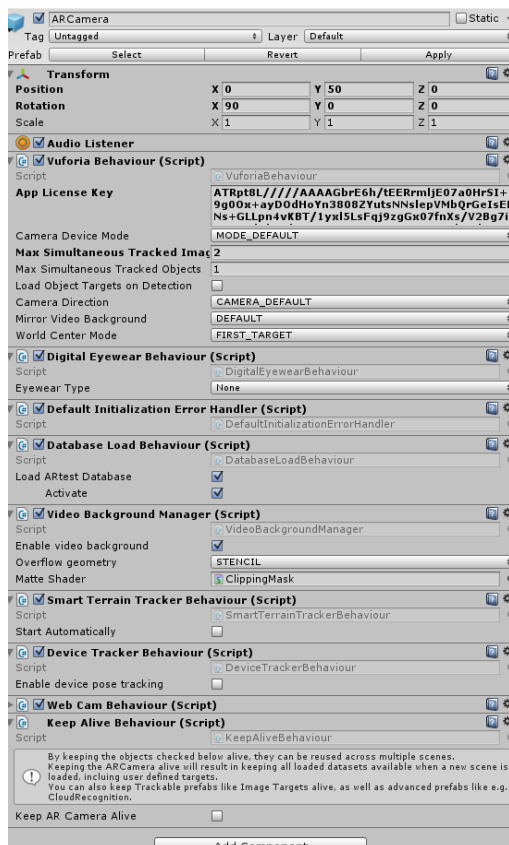
Then you will need an Image Target. In the image target behaviour script you need to select the database and image. After all this you are set to work in it.
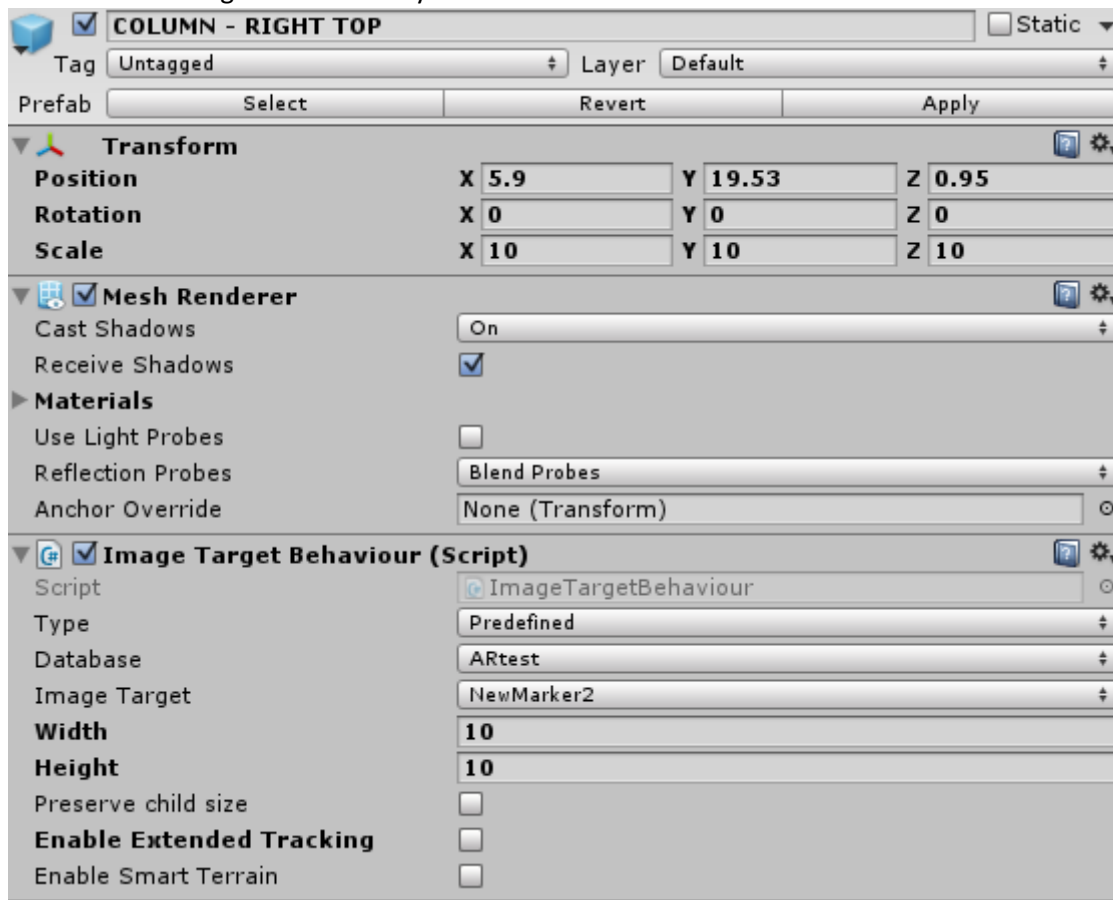
The basics are that you put your 3D meshes (I use meshes provided to me by the museum) as child of your image target. Whenever the camera recognizes an image, it will display all the children on the correct position.

What makes a good marker

As mentioned I will need to design a marker that can be easily tracked by the app. In my test I used the following image:

Fig.2

While at home this worked perfectly, in the museum it was a bit harder to read. The dimensions of this image are approximately 5cm by 13cm. I came to the conclusion that this marker is far from optimal to use.

So what is it that makes a good trackable image?

After some research I stumbled upon some pointers that should help me with creating a good functioning marker.

- Features
- Contrast
- No repetitive patterns

Features are sharp edged shapes that the tracker can detect. The image I created lacks this a lot. Only the letters contain some and the logo has 1 at each corner. There is also not much contrast. Only 3 colors were used which makes that the main parts consist of 1 color. This makes it harder to track. Repetitive patterns in my image would be duplicates of some letters.

Vuforia also has a built-in star rating that it gives to markers. My marker scored 3 stars out of 5 (at the time I had no idea what this star rating was). I will of course want to adjust my image and get atleast 5 stars of rating.

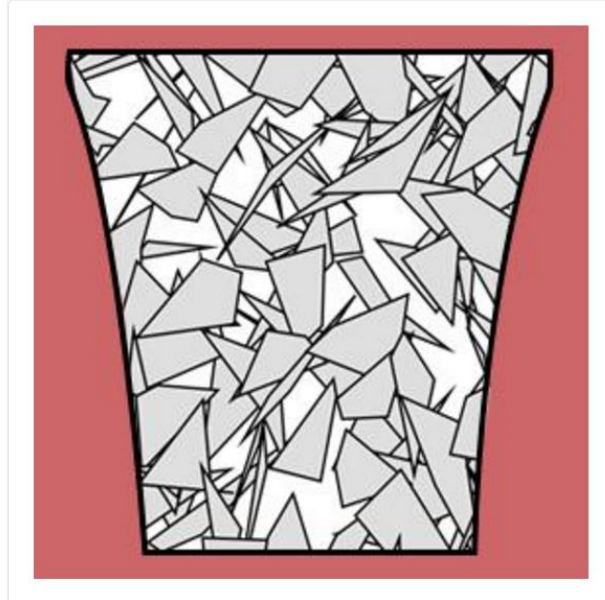So I came up with this marker (actually I generated[5] it).

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[5] http://www.brosvision.com/ar-marker-generator/
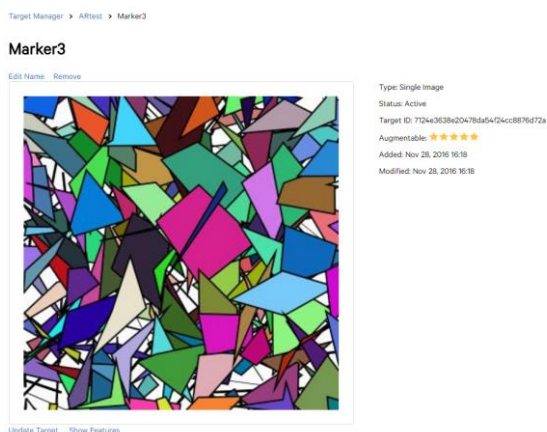
This one had a 5 star rating, but it's a pain in the eye to look at. So I tried something more special and less flashy.

My idea was to have a "broken" glass. It still looks a bit wacky but its at least better than the previous colormix. When I made this one I realized something else too. My tracking was a LOT more accurate with this last marker so I tried to figure out how this was possible. It this moment I discovered the show features button under the image. It seemed that vuforia had a harder time reading features on a colored image than a grayscale image.

For comparison I will show the 3 markers and show the increase of features that came with each update.
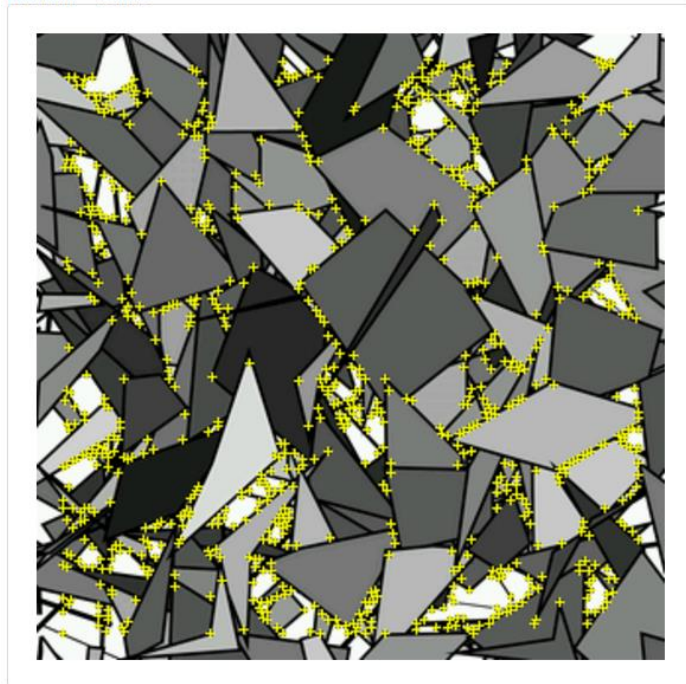
TestMark2

Edit Name   Remove

Type: Single Image

Status: Active

Target ID: f32edf574d2b4f1ebf829ed1bfdec289

Augmentable: ★★★☆☆

Added: Nov 2, 2016 16:06

Modified: Nov 2, 2016 16:06

Update Target   Hide Features

The first was the 3star rating. If we look at the amount of features, this seems a reasonable rating.

Marker3

Edit Name   Remove

Type: Single Image

Status: Active

Target ID: 7124e3638e20478da54f24cc8876d72a

Augmentable: ★★★★★

Added: Nov 28, 2016 16:18

Modified: Nov 28, 2016 16:18

Update Target   Hide Features

I thought I had hit a jackpot with this marker as the amount of features increased significantly compared to the previous one. But then I discovered this...

Marker_Distillation_1

Edit Name   Remove
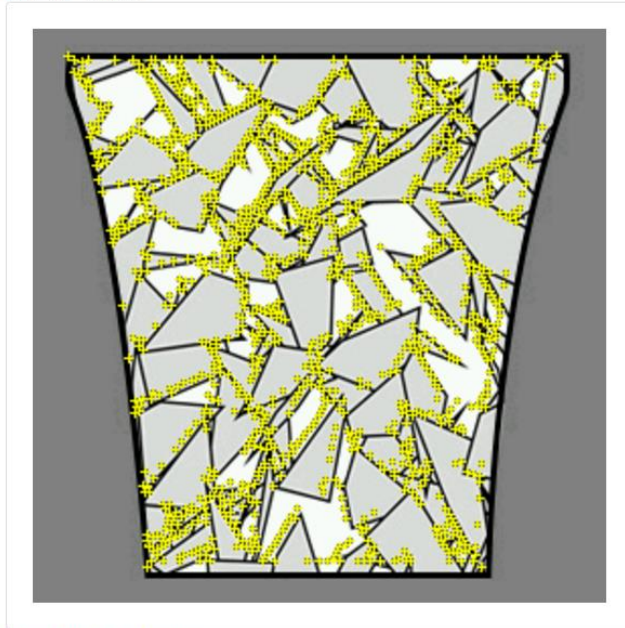
Type: Single Image

Status: Active

Target ID: beea290d56fa4dcfba92843c796c36e2

Augmentable: ★★★★★

Added: Nov 28, 2016 16:01

Modified: Dec 17, 2016 15:41

Update Target   Hide Features

I don't think it can be much better than this. And I could really tell it was much more stable than the previous markers. The amount of features is uncountable so I used these to continue working with.

As a small extra I also tried to see how a QR-code would do as marker. It was actually better than I expected and would be somewhere between the last and middle one in terms of amount of features.

9a6fbe03227264dffde2db017abbc8b8

Edit Name   Remove

Type: Single Image

Status: Active

Target ID: ccb1d17601d241598ad8d2f0040e8daa

Augmentable: ★★★★★

Added: Jan 25, 2017 20:33

Modified: Jan 25, 2017 20:33

Update Target   Hide Features

Other options to improve tracking

A different option I came across with, to improve the detection of a marker, is to use different camera focus modes. These focus modes are settings you can change when building your application.

"If the target is not well in-focus in the camera view, the camera image might result blurry and the target details may be hard to detect as a consequence, detection and tracking performance may be negatively affected."[6]
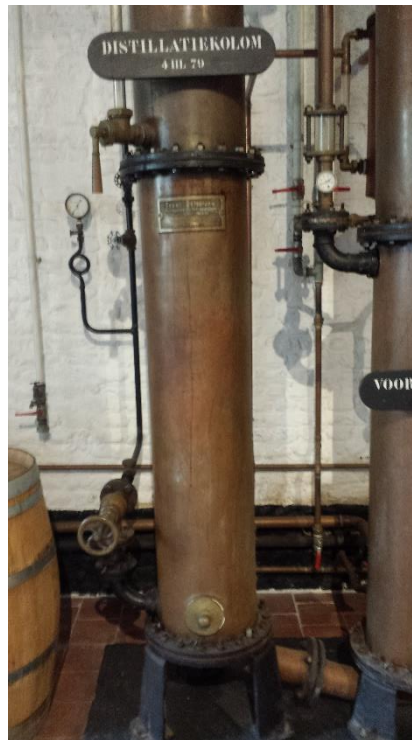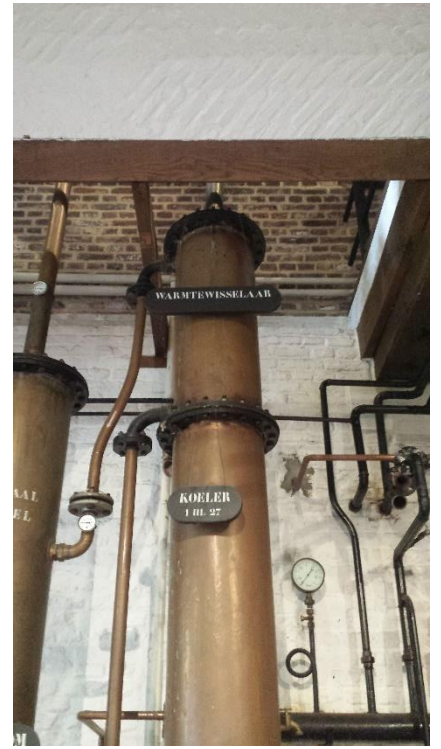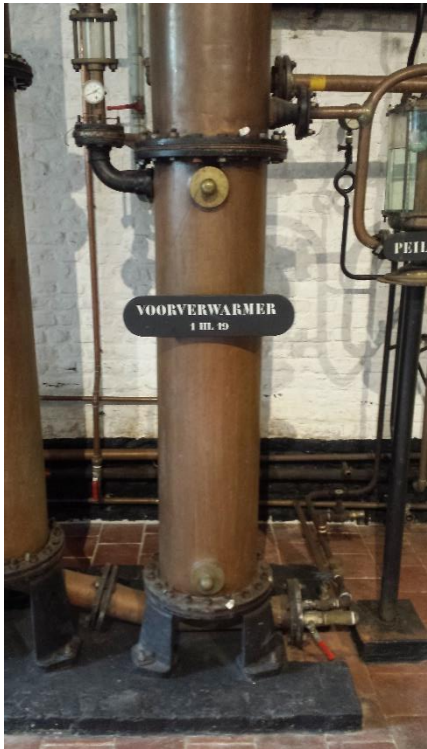
This is why using different focus modes may give a better performance.

Also making the target marker larger will help in detection, especially if the target is relatively far (think about the top compartment of the cylinder).

Placement

As I visited the museum I thought about how and where to place markers. I took pictures from angles that seemed to give the best vision, and where the visitor would most likely be standing. I was not allowed to place markers on the cylinders itself as they get very hot. But they have name plaques where I can attach them to. These plaques stay on the distillation column forever, so there should be no worries that there would be any misalignment (unless a visitor knocks the plaque over).

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[6] https://developer.vuforia.com/forum/faq/how-can-i-improve-detection-and-tracking-stability

5.Distillation column

To create an application that explains how a distillation column works, we obviously need to know how this thing works from bottom to top. The following section of this paper will cover what the function is and what happens.

Distillation column?

A distillation column generates alcohol. It does this by separating volatile substances from non-volatile substances. The start product is fermented mash called "wort". In the end we will have a substance called "flegma" or phlegm that consists of 35% alcohol and a vaster liquid is formed called "draf". This draf is used to go back to the farm to feed the cows.

What does it look like?

The distillation column (fig. 1) consists of 2 big cylinders connected with tube. The height reaches a maximum of 4.62 meters. Each cylinder has a diameter of 45 centimeters. It is mainly made out of copper, brass, iron and glass. 1 of the 2 cylinders consists of 3 compartments (the right one on fig.1). The first compartment at the bottom is called the "voorverwarmer" or preheater. The second compartment in the middle is called the "koeler" or cooler. The third and last compartment is called the "warmtewisselaar" in English known as the heat changer.

The other cylinder is where the actual distillation takes place and therefor it is just called "distillatie kolom" or distillation column in English.

The process

I will only clarify the process the distillation column itself performs. There are some many other things going in before and after this process, but as they are not relevant for this research I will leave them out of this paper.

It all starts in the right column (fig.1) in the "voorverwarmer". In the bottom wort gets pumped in which enters a tube that takes a spiraling motion upwards. This spiraling tube is at first surrounded by hot steam and later by a hot substance called "draf" (more info about "draf" later). This will heat the "wort" in the spiraling tube. At the top of the spiral, the wort temporarily leaves the cylinder in a tube so that it can be pumped to the top compartment of the column, the "warmtewisselaar". In this compartment the wort gets heated up even more by, at first steam, and later on a gas. At the top of the "warmtewisselaar" the "wort" will enter another tube to change to the 2nd column to the left.

At the bottom of this column steam is getting inserted. This steam will rise and take alcohol components from the "wort" with it. Thanks to heating the wort the alcohol parts inside are changing into a gas (alongside other components apart from the alcohol. The wort falls down on discs and steam passes from the bottom to the top. The wort doesn't cool down because of the steam and when it reaches the bottom almost all the alcohol is evaporated in the steam. This non-alcohol wort is called "draf" now and drops down. On the bottom of the cylinder is a tube that connects back with the first cylinder. The formed "draf" will go back in the first compartment where it will heat up new incoming wort since this "draf" is still hot. When the "draf" reaches the top of the

first compartment it will go through the tube on the right for storage. This "draf" can be used later on to feed cows or other livestock.

Now back in the second column where the steam takes the alcohol components from the wort. As I mentioned this gas is now a mix of mainly alcohol and water. On the top of the second column this gas goes back to the top compartment of the first column through a tube. This hot gas will now condensate on the top compartment and give off its heat to the spiraling tube that contains the new "wort". As the gas condensates and becomes liquid again, it will drop down and eventually go through small pipes at the bottom through the middle compartment.

This compartment is filled with cold water (starting at the bottom) and will cool down the still warm condensation inside the pipes. This condensed water/alcohol is called "flegma". At the bottom the "flegma" will leave the cylinder and will go through a measuring glass that shows how high the alcohol percentage is. The "flegma" will continues through tubes and will be stored in a big vessel that will hold it before it goes through a second distillation. This second distillation is a different process and will not be discussed.
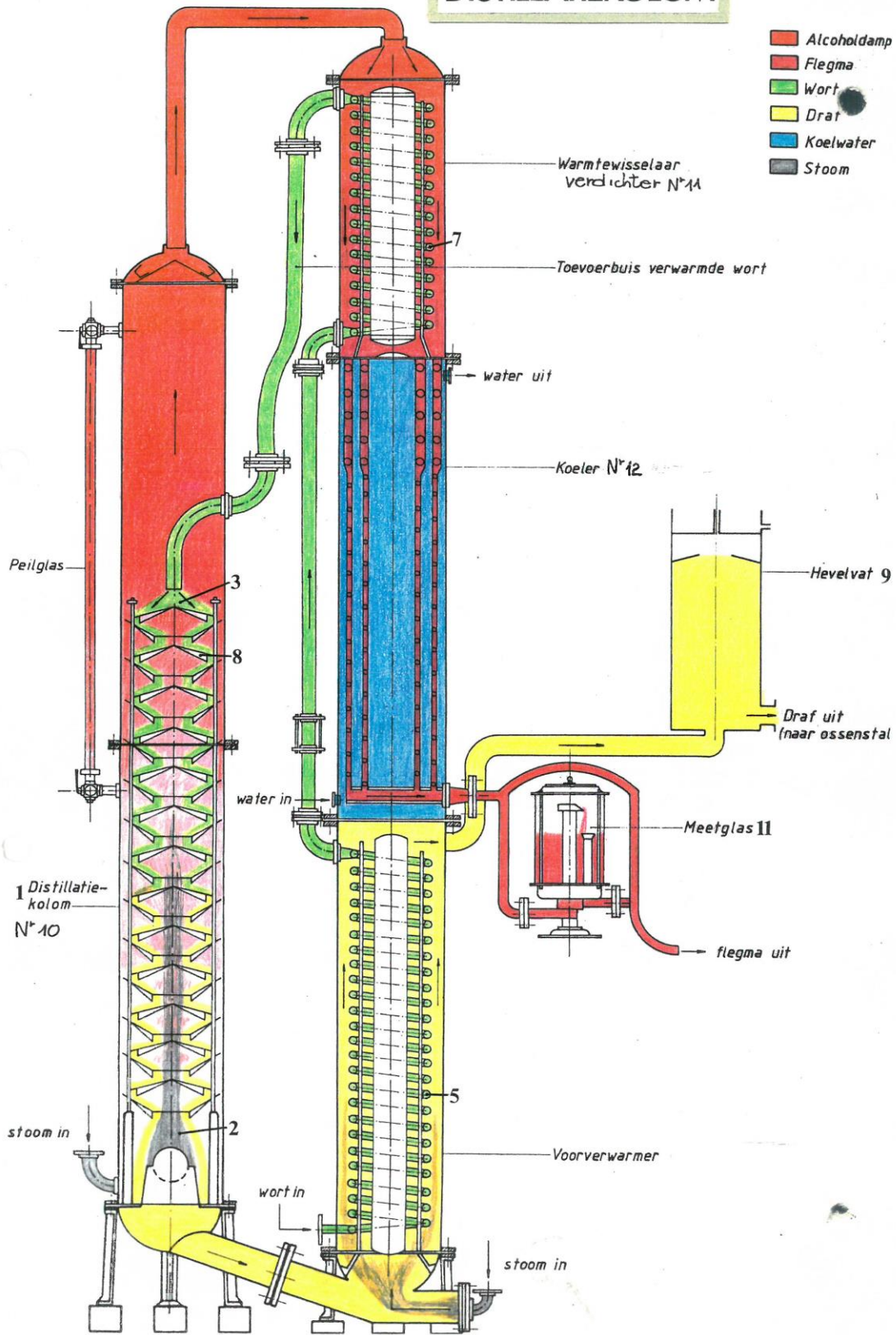
DISTILLATIEKOLOM   PLAN XV

	Alcoholdamp
	Flegma
	Wort
	Draf
	Koelwater
	Stoom

Warmtewisselaar verdichter N° 11

7

Toevoerbuis verwarmde wort

water uit

Koeler N° 12

Hevelvat 9

Peilglas

3

8

Draf uit (naar ossenstal

Meetglas 11

water in

1 Distillatie-kolom N° 10

5

Voorverwarmer

stoom in

2

wort in

stoom in

flegma uit

Fig.1

6.The problems

There are a few problems that pop up at first glance.

1. Height
2. Light
3. Make it clear

1. As the columns are very big, it is almost impossible to keep track of a marker as the user wants to view certain parts of the machine. Also because of the height it might be difficult to track a marker that is placed relatively far away.

2. The room where this machinery resides is relatively dark. So it might get difficult to track a marker.

3. There are a lot of things happening at the same time. Making that clear in this application is not an easy task to perform.

7.Approach

Problems are here to be solved, and after some brainstorming I came up with a fun idea that should explain everything very clearly and is very visual.

The first 2 problems are a marker related thing. The most important aspect will be to create a big enough (not too big) and clear defined marker, also the use of multiple markers should solve a big part of the problem. Every compartment should have its own marker. In my next chapter I will define what makes a good marker.

The third problem is how I will explain the whole process to the visitor. This essentially determines what the app will look like and what it will augment to provide the needed info.

I was thinking of a system where the visitor just aims at a marker with their phone and gets an inside view of the designated compartment. The markers are numbered so the visitor can start at number 1. The visitor then sees 1 blob of wort. With controls the visitor can go to the next step where the blob passes through and he gets a note of text clarifying what happens. Small animation such as heating up the wort will be displayed as well to make it visually clear and understandable for people that do not know any Dutch.

8.The final product

Additional problems

After having created a prototype that fully worked I went back to the museum. The app was working as described in my approach. You had a see-through look of the distillation column and you would follow wort through the whole system. Info could be toggled on and off and it was very entertaining to watch at.

The only problem for the museum was the fact that the markers were so big. To get a stable tracking an image of 20x20cm was required. This was because the user had to stand quite a bit back to see the whole picture.
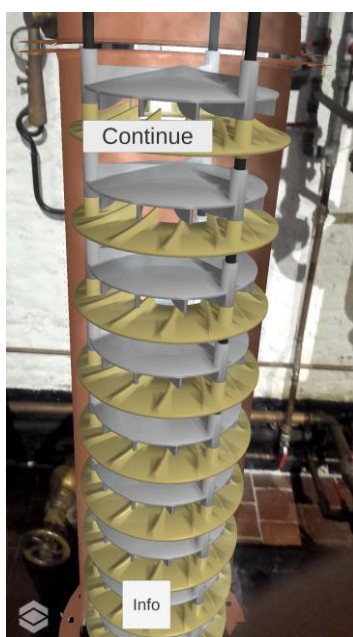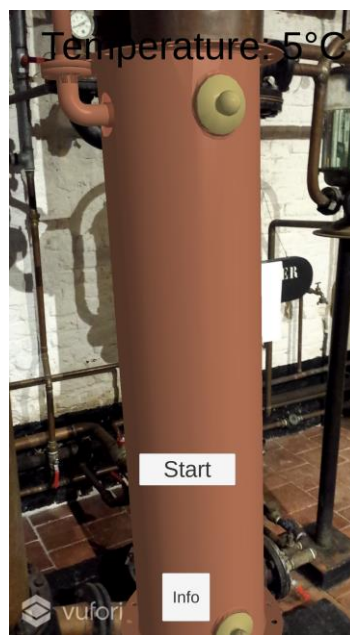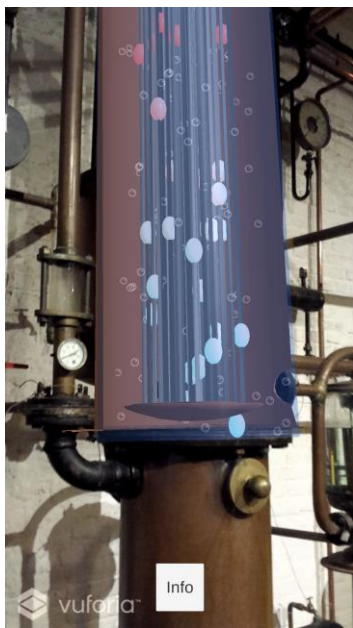
Brainstorming to a potential solution

To solve this marker issue, Joanie and I had a small brainstorm on how to approach it.

After some thinking we wanted to no place the markers on the column itself. But instead use 1 marker than would stand on a stand that the use could aim at. The user can then have 1 full view of the whole distillation column. So basically everything wrapped under 1 marker and this marker could then be placed anywhere.

As the scope of my research work is about the usage of markers I proposed to work out both ways. So 1 application that uses the fact of having multiple markers. And another one that will have everything in one marker. After telling my mentor this he also told me to focus the most on the one that has multiple markers.

The final product

I tried to refine my prototype to a user friendly app. I also added some more particles and found a better way to display the info. The final looks a bit like this:
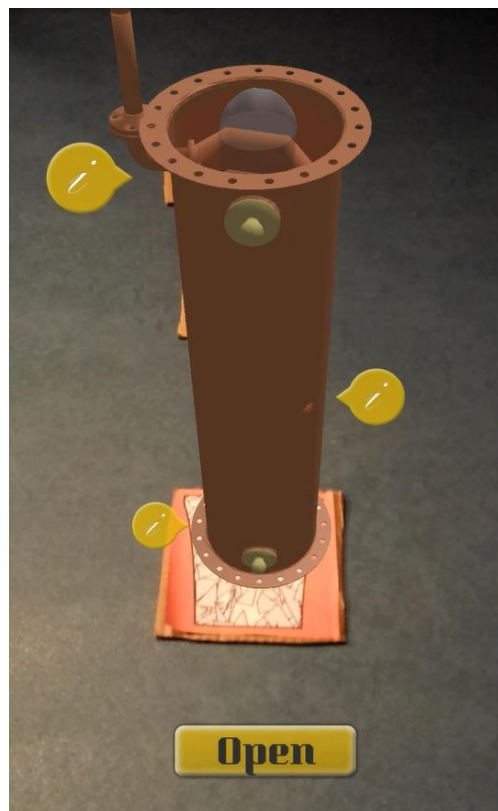
Above is for the separate markers.
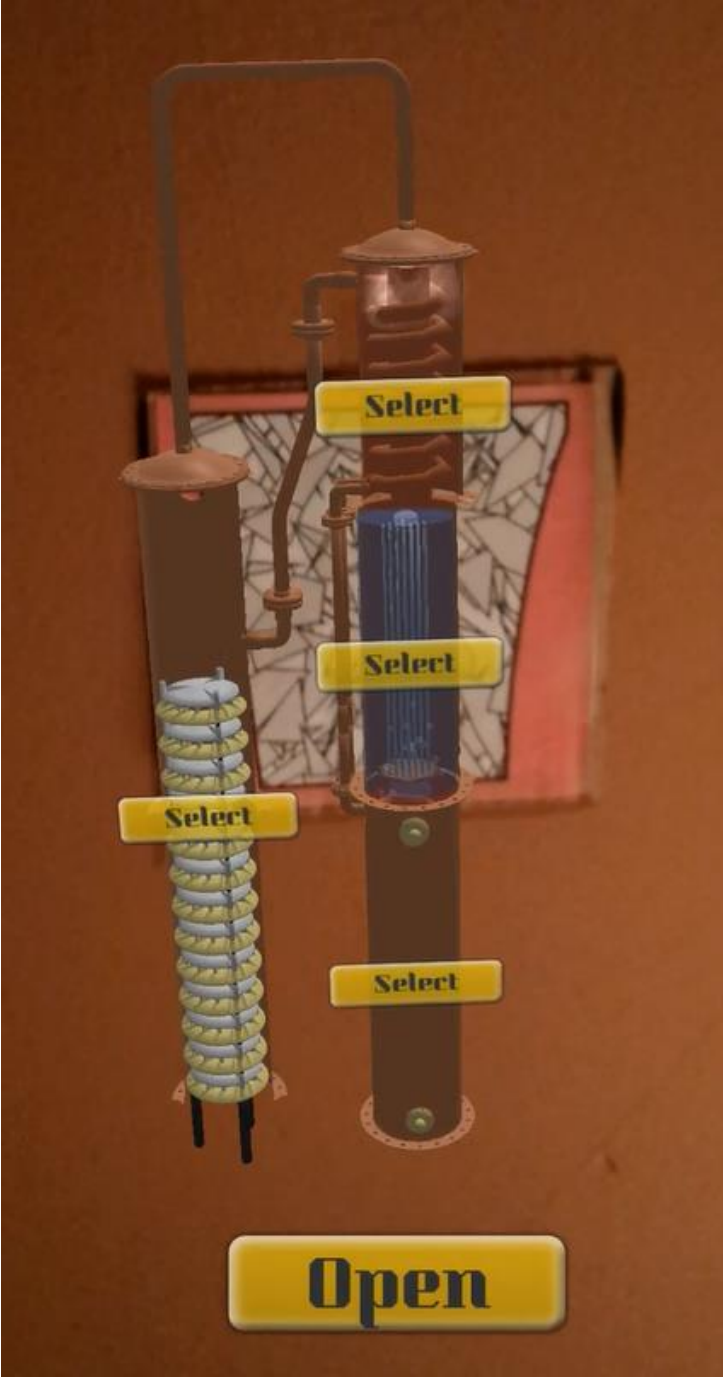
This is for everything in 1.

9. Conclusion

The end results both have their pro's and con's. The separate one is easier to overlay with the real machine, but needs big markers. The all in one application gives a clearer overall picture but loses the augmented reality feel.
As augmented reality project I think the application with separated markers is ideal to show the potential of AR. The only downside is that the machine is very big and the markers lose their trackability from far away.

I feel that as it is now, it can't be used in the museum. They gave me feedback aswell and would like to try different methods (not using markers) to visualize my application over their machine.

Another way to implement it would be on one of their touchscreens. They have 3 touchscreens but they all show the same. The application with 1 marker could easily convert into something without a marker.

So my final conclusion for this project will be:

The marker system has 1 big drawback. It looks weird and has to be big. Maybe I've used the wrong SDK as base and is this vuforias problem. But I feel that this problem would occur with other SDKs too. The machine is just too big to cover efficiently.

9.References

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