SeeFood

AUGMENTED REALITY MENU

Master Thesis

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SeeFood: Building a startup for augmented reality restaurant menus
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Executive Summary

This master thesis describes the self initiated graduation project on SeeFood: an augmented reality menu app for restaurants. The project was set up as an entrepreneurial project, with the goal of developing a basis for continuing with the idea as a startup after graduation. To be able to create SeeFood, this project relies heavily on two technologies: augmented reality and photogrammetry.

Augmented reality (AR) is the addition of virtual objects into the real world. The user is still interacting with the real world, but these virtual objects can be perceived within their vision of the real world.

Mobile augmented reality is currently a big trend, with all the big tech companies investing in this field. While it is still the early days for this, there is a huge potential for what AR can become. It will likely still take a few years before a large majority of consumers will own AR compatible phones, but AR is at a stage now where it would make sense to invest in it. Betting on the predictions that the technology will become huge in a few years.

Photogrammetry is a type of 3D scanning, it is a technique to turn real objects into photorealistic virtual 3D objects through the use of photographs. This technology is used to create photorealistic 3D models of restaurant meals. Making it possible to view these meals at 1:1 scale in augmented reality, so that a restaurant visitor can actually see what they would get.

Photogrammetry works by using photographs taken all around an object, from these it is possible to recognize feature points (contrasting pixels) in the photos. Matching these points between photos, it is possible to calculate the camera locations and reconstruct the 3D geometry of the object. Finally, adding the photos as a texture makes the model look photorealistic.

The 3D scanning market is rapidly evolving, especially mobile photogrammetry still seems immature and will likely change drastically in the next few years. Allowing anyone with a smartphone to make their own 3D models, although the quality of these models will likely not match the quality of photogrammetry desktop applications anytime soon.

In order to 3D scan food items, a photogrammetry scanner had to be developed. This scanner will eventually become fully automated, so that it can create scans with one press of a button.
Next to the scanner, the idea of SeeFood also required the development of a menu app. This app was developed with a specific tablet device in mind, as that could guarantee a consistent good experience when used.
It would be advised for restaurants to switch to digital tablet menus, at least for the time being until nearly everyone has a phone that is capable of AR, making it possible for people without AR capable phones to still experience the menu the way it is intended.

AR menu competitors like FoodStory are aiming for restaurants visitors to install the app on their own devices, and assuming people will later use it during a restaurant visit. Whether that is a good strategy seems debatable, as FoodStory seemed to have gained little traction after launching their app.
Online menus for mobile ordering are perhaps the most promising new contender for digital menu solutions. While they have been tried before 10 years ago and failed, a new wave of startups in 2018 is now again trying to make this happen. This time it might very well succeed, as these menus provide the cheapest possible solution for the biggest problem in the restaurant sector right now: expensive employees.

When interviewing restaurant owners, the difficulty to find new employees and their high costs (sometimes up to 50% of the revenue) was one of the most pressing issues at this moment. This is also a national trend, as there is a tight labor market currently in The Netherlands, causing many restaurant vacancies to go unfulfilled.
The possibility to automate some staff functionality, by allowing guests to order and/or pay through an app, were more than welcome to restaurant owners. As they did not seem hesitant at all to cut staff when it could save them money.

Such ordering and paying functionalities are therefore one of the most important features to build into SeeFood, while still maintaining the 3D food models as a unique selling point over existing mobile ordering apps.
The price is estimate for SeeFood is that it should cost around €150/month if a restaurant wants to make use of the service, which includes the lease of the automatic 3D scanner and a license to use the application. Additionally, restaurants can choose to lease tablets for €15 per tablet per month.
A €200 one-time setup fee will also be charged. While the time invested into acquiring a new customer and getting them up and running would likely be more costly, this investment would be earned back over time through the monthly €150 subscription fee. The one-time setup fee therefore serves as somewhat of an assurance that the restaurant is serious about using SeeFood, lowering the risk of customers cancelling the product in the first few months. Charging a higher initial fee or creating yearly contracts likely would not be received well by restaurant owners, who stated during interviews that they want to take a big financial gamble on whether something new would work for their business.

In the future SeeFood will be able to run as a web app, eliminating the need for customers to download an app to their phone. Users can scan a QR-code at the restaurant table and will be directed to the SeeFood web app, which immediately knows at which table they're sitting as each table features their own QR-code. So when the user decides to order something, the restaurant will know who to deliver it to.

With opportunities in the restaurant market and positive reactions on SeeFood, a final decision was made to indeed continue with this project as a startup. But the search for finding product/market fit should still continue, as there does not seem to be one very clear opportunity that SeeFood could fulfil perfectly yet.

Glossary

SeeFood – Name of the startup idea that is developed in this thesis. SeeFood in an augmented reality menu for restaurants that helps their visitors make a better choice in what they want to eat. Visitors will be able to browse the menu on a tablet and see 3D models of each meal projected at 1:1 scale on their table in augmented reality.

Horeca – A syllabic abbreviation for the words **Ho**tel, **Re**staurant, **Ca**fé, describing a specific part of the food services industry. The term is commonly used in The Netherlands.

Millennials – generation Y, people who are 22-37 years old in 2018.

Centennials – generation Z, people who are 6-21 years old in 2018.

Early Adopters – People who are among the first group of people to embrace and start using a new product.

BYOD – Bring Your Own Device.

Lean Startup – A methodology for developing businesses and products aimed at reducing market risk and minimizing the need for high investments.

MVP – Minimum Viable Product – A (first) version of your product that customers would still accept, with the intention of creating this version as quickly as possible.

Pivot – Quickly changing the direction of a product or idea in to test a new strategy.

Problem/Solution Fit – Discovering a solution that solves a problem worth solving for a big enough part of the population.

Product/Market Fit – Having built something customers are willing to pay for, thus having validated your business model.

LOI – Letter of Intent – A method to test whether customers are willing to pay for your product before the product exists. This is done by creating a letter that closes a deal between two parties.

USP – Unique Selling Point – Beneficial features of a product that competitors lack.

Scalable Business – A business that can maintain (or even increase) their profit margins when sales volume increases.

B2B – Business to Business – When a business sells their products to other businesses.

B2B2C – Business to Business to Consumer – When a business sells a product to another business, but the other business will make the product available to consumers.

AR – Augmented Reality – The addition of virtual objects into the real world. The user is still interacting with the real world, but these virtual objects can be perceived within their vision of the real world.

ARKit – Apple's augmented reality framework available for recent iOS devices.

iOS – The mobile operating system Apple uses on their iPhones and iPads.

ARCore – Google's augmented reality framework available for some Android devices.

Android – The mobile operating system developed by Google that is installed on a variety of phones and tablets.

Xcode – An IDE (integrated development environment) developed by Apple intended for development of iOS and Mac OS applications.

Photogrammetry – A 3D scanning technique to turn real objects into photorealistic virtual 3D objects through the use of photographs.

DSLR – Digital Single Lens Reflex-camera

Texture – A texture is an image meant to be applied to the surface of a 2D or 3D model to give the model a certain visual appearance.

Mesh – A geometric 3D object that is described through a collection of vertices (points), edges (lines) and faces (flat surface enclosed by edges)

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2. EXPLORE

Covering the insights gained from desk research. Exploring the trends and data that is available online. Reading this chapter will give you the context around SeeFood.

3. VALIDATE

The core idea of SeeFood is tested using market validation. A series of interviews with people in the target market were conducted to determine whether the concept has potential in the market.

4. MAKE

3D food models need to be created. In order to improve the quality and speed of capturing the photos for these models, a scanner had to be developed. Lastly, with the 3D food models available, an app for SeeFood was prototyped.

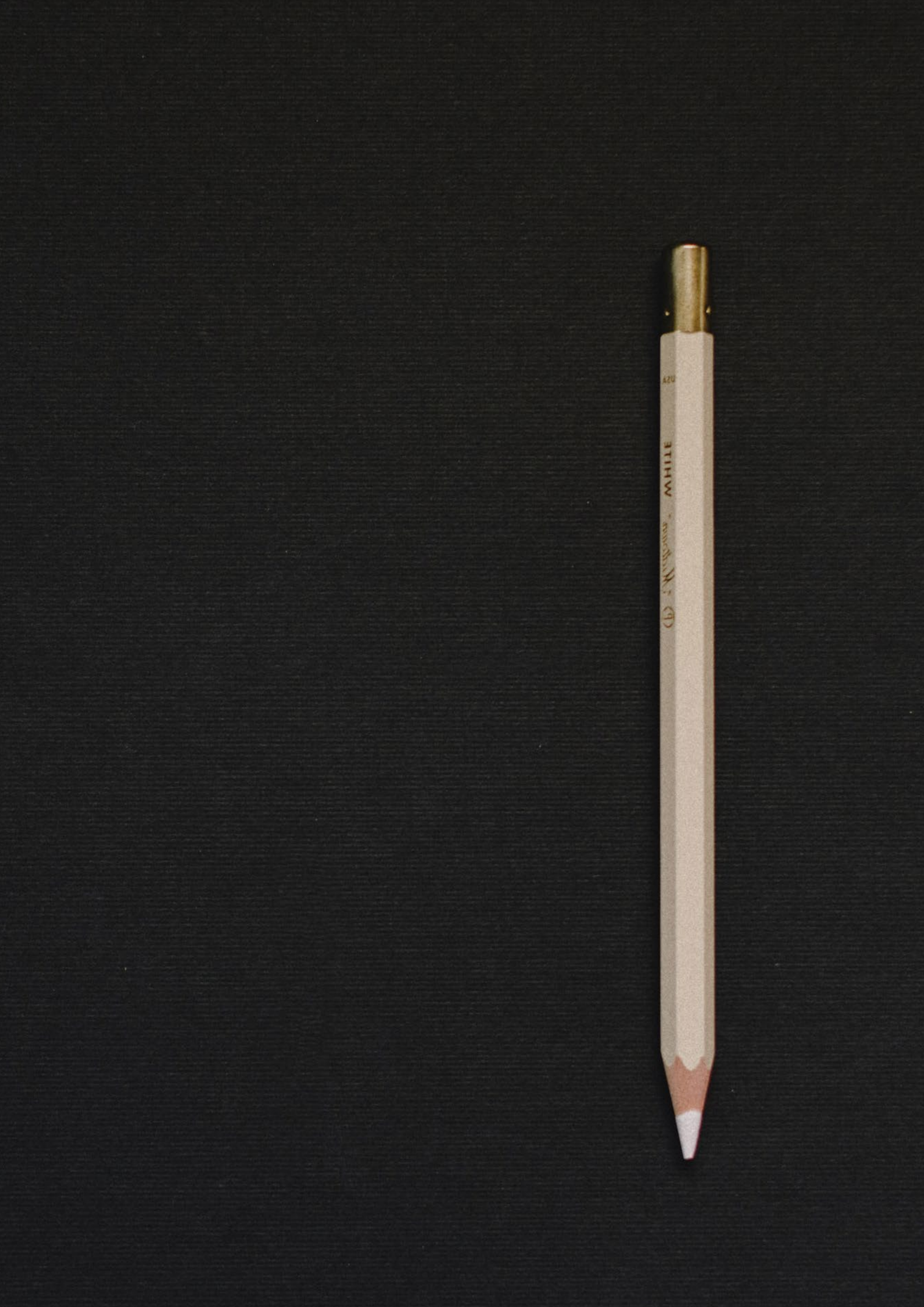
Appendices available as a separate document

01

DESCRIBE

In this chapter

This chapter lays a scope and purpose for the project. Describing the assignment in the project brief, the approach taken in the project, and giving an introduction on the technologies this project evolves around.


WHITE

1.1 Introduction

Me

Dorus van den Oord

"When I go to restaurants, I am always in doubt of what to order. I am often anxious to receive something on my plate I will not like, or that is way too small for my appetite. With digital products all around us nowadays, I wondered why no one has digitized the paper menu."

In search for a thesis subject, I looked at new upcoming technologies. The 'next big thing' is predicted to be augmented reality (Volkskrant, 2017), with tech giants such as Apple, Google and Facebook all putting big efforts into developing their own smartphone AR platforms. Looking at the possibilities of this new technology, I saw an opportunity to innovate the restaurant menu.

The idea to innovate the restaurant menu immediately clicked. The need for change was validated through my own problems during a restaurant visit, the technology was there to realize it, and as a project this idea contained many aspects of my personal interests. These aspects were the combination of technology, photography and nutrition.

In January 2018 I started my graduation project on SeeFood, with the ambition of creating a product that customers actually can and want to buy, and with the hopes of making it possible for SeeFood to continue as an actual startup after graduation.

1.2 Project Brief

The objective of this graduation project is the exploration and realization of the idea of augmented reality menus for restaurants. It is assumed that restaurants experience problems with their current menus: the menus are not able to dynamically alter to the live situation, they cannot easily be changed, details about dishes might need to be emitted due to lack of space, they are a one-size-fits-all solution that lacks customization, and customers have no good way of seeing upfront what they would get.

A digital menu could potentially solve nearly all of these problems, and the addition of 3D food models and augmented reality can be the most realistic way possible to show what is on the menu, which was the initial main problem that lead to this project. It will also generate appetite, likely making customers order more. The idea is also novel to customers, triggering a ‘wow’ response that makes the restaurant experience unforgettable and which could lead to free publicity for the restaurant.

This project should validate if these assumed problems are important to customers and to restaurant owners; do they want the product? The addition of augmented reality should also be considered: Do customers want this, and is it feasible to bring this to market?

Next, the technology should be considered. The idea envisions showing 3D food models in augmented reality. But how can this be developed. What is possible within the realm of augmented reality, and how can appetizing 3D food models be created? Photogrammetry seems like a promising solution to this, but other 3D scanning techniques should also be considered.

The end result is expected to be a (digital) product, that can serve as a complete new menu solution to restaurants. For this, a scanning solution likely needs to be built, in addition to developing the workflow to create the 3D models from these scans.

Finally, the business part needs to be considered. Redefining what the product and its context should be based on earlier learnings. Defining where the value is and how that can be turned into a profitable startup business; can this project be a viable startup?

1.3 Approach

The basic design cycle

The typical IDE design approach (see figure 1.1) is not a right fit for this project. This approach goes through a linear design process with only some iteration cycles. As this project is chosen to be a self-initiated graduation project with the goal of forming a startup, there is no existing knowledge from any company. This leads to many more uncertainties and assumptions about the market throughout the design process. In order to get to a product in the end that could become a viable startup, a more iterative design approach is needed. This approach is to be found in the Lean Startup method.

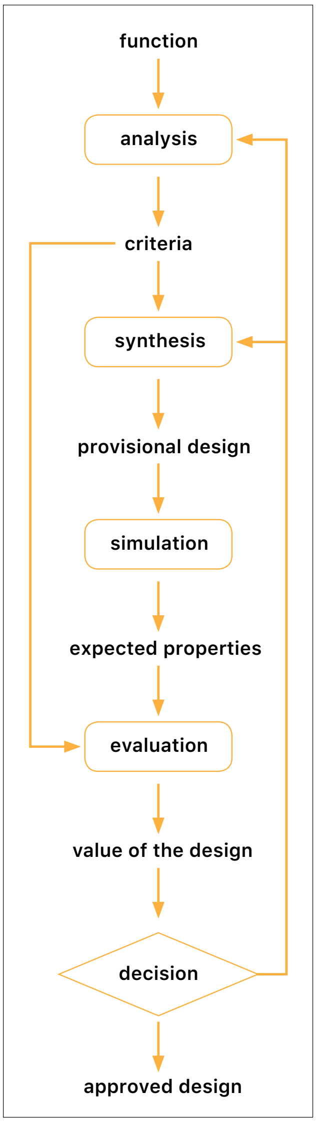


Fig. 1.1: Roozenburg & Eekels 1995, The basic design cycle

What is a startup

There seems to be no unanimous definition of what a startup exactly is. While some might argue that it is simply a small company, or a company that has just started, these definitions lack what sets them apart from other companies and what makes startups be seen as more innovative than big companies. A popular definition to describe this is by Steve Blank, a former serial entrepreneur in Silicon Valley who is now an academic professor. He describes a startup as:

"A startup is a temporary organization designed to search for a repeatable and scalable business model" (Blank, 2014)

Contrary to his definition of a startup, he would describe a company as:

"A company is a permanent organization designed to execute a repeatable and scalable business model." (Blank, 2014)

Big companies used to be startups in their past when they were still searching for their business model. However, having found a repeatable and scalable one, their focus shifted towards the execution of that business model. This different focus is why many companies lack innovativeness according to Steve Blank.

Lean startup

Immensely popular within the startup world is the lean startup approach (Ries, 2011) to new product development. This methodology aims to shorten the time it takes to learn if your idea is successful. This way, startups can validate a lot of different ideas and quickly discard ideas that do not work.

The basic principle within lean startup is the build-measure-learn feedback loop. Where it is crucial to start building your product as soon as possible (build), show it to potential customers to get feedback (measure), draw conclusions from that on how to improve (learn), and iterate this loop.

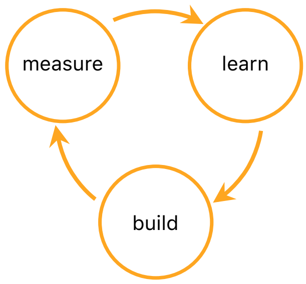


Fig. 1.2: Eric Ries 2011, The build-measure-learn feedback loop

Integrating design thinking

As the lean startup methodology is very developer focussed, some parts of a design process should be integrated in order for it to fit better into a design project. For this, aspects from design thinking have been taken and integrated into the approach. These design thinking aspects are meant to develop empathy for the user, and get a thorough understanding of the context.

This project will begin with a research phase based on design thinking where the context and users are analysed. This forms the necessary basic knowledge around the product.
After this initial research phase the project will go into development cycle where the lean startup build-measure-learn feedback loop will be used for the rest of the project. Meanwhile, the initial insights from the research phase will again be reflected on after every cycle. Applying the learnings from development and testing to the insights from the research phase, discovering whether a change should be made to the problem space.

During the build phase some even quicker iterative agile cycles will done. This allows for quickly testing new things and deciding whether they are worth investing more time in.

This thesis forms a summary of the progress made throughout this entire approach (see figure 1.3). Rather than elaborating on each cycle, for readability the thesis is structured again more like the typical IDE design approach.

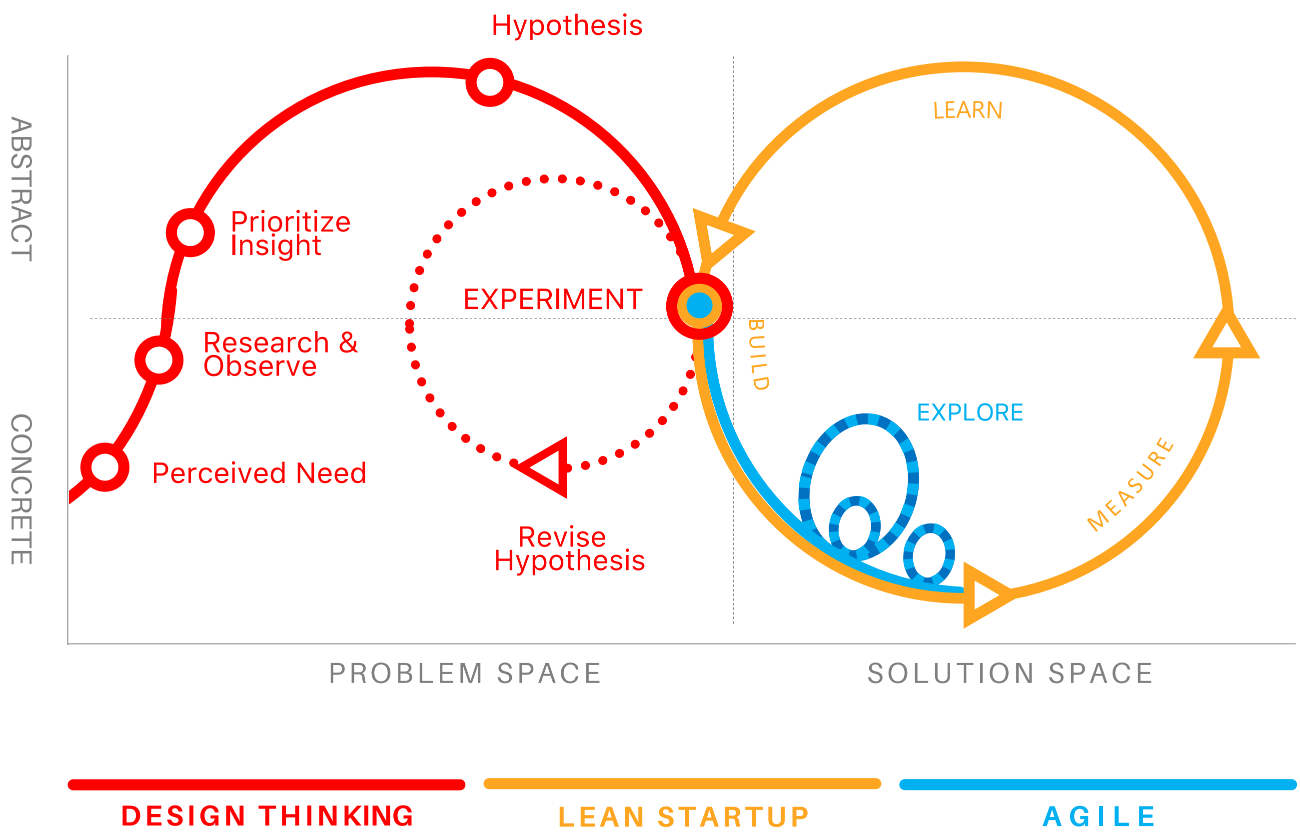


Fig. 1.3: Design approach used in this project. Combining a design thinking approach with lean startup

1.4 What is AR

In order to give a definition of what augmented reality (AR) is, we first need to take a broader look across the whole extended reality (XR) spectrum. This spectrum ranges from the real world to a complete virtual world. In 1994, different stages across this spectrum were defined by Milgram and Kishino (Milgram and Kishino, 1994). Their spectrum consists of four different stages (see figure 1.4): Real Environment, Augmented Reality (AR), Augmented Virtuality (AV) and Virtual Environment.

Real Environment is exactly what it describes, this is the real world without any added digital or virtual elements.

Augmented Reality (AR) is about overlaying the real world with virtual elements. The user is still interacting with the real world, but virtual objects can be perceived within their vision of the real world. Think of Google Glass as an example, which displays a small translucent screen within the corner of your eye.

Augmented Virtuality (AV) can be seen as the inverse of augmented reality. Where the user is interacting with the virtual world but perceives real objects within this virtual world. An example of this would be a video-conferencing application. Where the user is interacting with other real people in a virtual environment, while these other people might be thousands of kilometers away in the real world.

Virtual Environment is when a user completely interacts with a virtual environment. This is often what is referred to as Virtual Reality (VR), however, virtual reality can also be augmented virtuality.

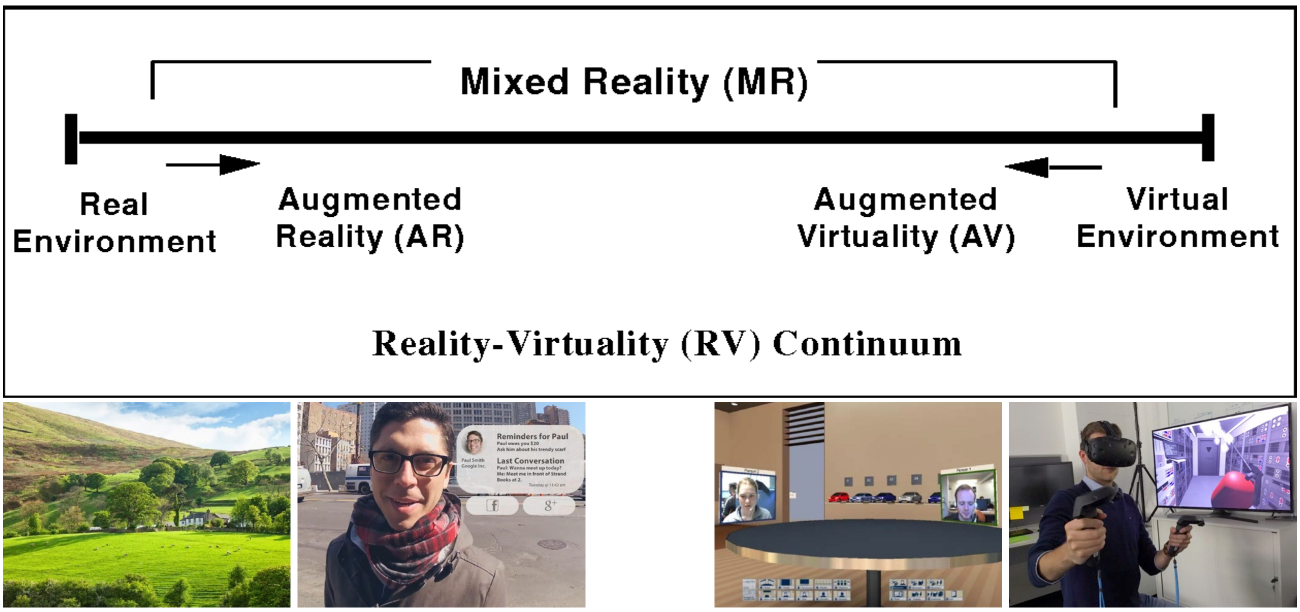


Fig. 1.4: Milgram and Kishino 1994. Reality-Virtuality Continuum

Mixed Reality

But there is one more category that does not fit on a single place within this spectrum, and that is Mixed Reality (MR). Mixed Reality can be seen as an experience that covers nearly the whole spectrum, blending augmented reality and augmented virtuality into one experience. It most closely resembles augmented reality, because the user still experiences mixed reality within the real environment. The key difference being that the virtual objects would behave as physical object. So, a virtual ball thrown in mixed reality should bounce off a wall or a floor as if it were a real ball. Similarly, a virtual table placed on a real floor should stay at the same physical place when the user walks around it or views it from a different angle.

What is often referred to as augmented reality in the media nowadays is actually mixed reality according to Milgram's and Kishino's continuum. However, there is no clear line when augmented reality is to be considered mixed reality, since mixed reality is a spectrum which contains augmented reality. For the sake of consistency with the current naming conventions in the media, the rest of this report will refer to either augmented reality or mixed reality in the same way these terms are used in the media.

Fig. 1.5: Saab 2016. Mixed Reality application intended for use by the Royal Australian Air Force

Types of augmented reality

Within the realm of augmented reality, three different types of AR systems can be defined: Geospatial, 2D, and 3D (Curran, 2016). Rather than being substitutes for each other, these types can be more seen as a development over time. Where currently only the last two, 2D and 3D AR systems are still widely used.

For this project the focus will be on the third one (3-D AR systems), using either a smartphone or tablet to display this type of AR.

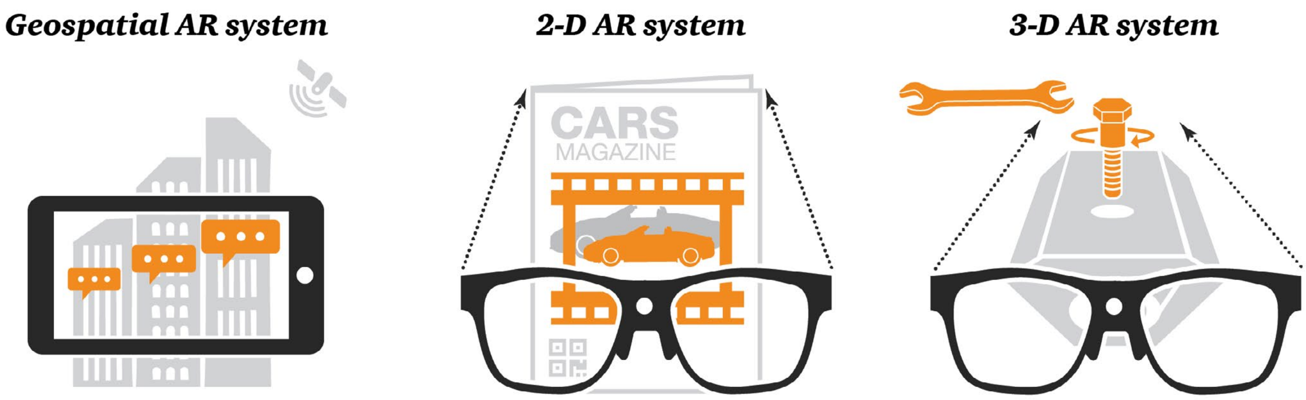


Fig. 1.6: Curran 2016, The three primary categories of AR systems

Geospatial AR is using the GPS of the device and its digital compass data to determine the location and orientation. Using this data, the application can display information about the real world as an overlay of the camera view. These systems were often the earliest form of mobile AR, as for example Layar version who has been developing this since 2006 (see figure 1.7).

This type of AR recognizes predefined objects (or markers) through a camera and displays digital content on that item. This came with technological advances where devices would be able to recognize patterns within the camera view. This technology became popular for usage in newspapers and magazines. With version 6.0 Layar also introduced a 2D AR system (see figure 1.8)

With 3D AR, the device is able to recognizing and track its own position in the real world, making it possible to place virtual 3D objects in the world that are at 1:1 scale and stay in place even when the device is moved.
This can be done using smart glasses, but also with a headset or a smartphone or tablet. For example, Layar added such 3D features in 2014 (see figure 1.9)

Fig. 1.7: Layar version 2.0 (2009)

Fig. 1.8: Layar version 6.0 (2012)

Fig. 1.9: Layar's interactive 3D features (2014)

1.5 What is Photogrammetry

Photogrammetry is a technique to turn real objects into photorealistic virtual objects through the use of photographs. The key underlying mathematical principle to this is triangulation (see figure 1.10). By finding points on the object that are present in multiple photos, the location of these points in 3D space can be calculated trough triangulation.
However, for triangulation to work it is necessary to know the location and orientation of each camera in the same 3D space. In order to calculate these, it is necessary that there are multiple points on the model that can be seen by at least three cameras (see figure 1.10). From this the locations and orientations of the cameras relative to each other can be computed.
By moving the camera around the object and taking photos from different directions and heights the full 3D geometry of the object can be recalculated, if each point on the object can be recognized as the same unique point in multiple photos.
With the locations of the cameras and with their orientations towards the 3D model known, a photorealistic texture can be generated and applied onto the model (see figure 1.11).

Next to photogrammetry there are other methods of turning real objects into virtual objects, these methods will be explored further on in the 3D-Scanning market analysis in 'Chapter 2: Explore'.

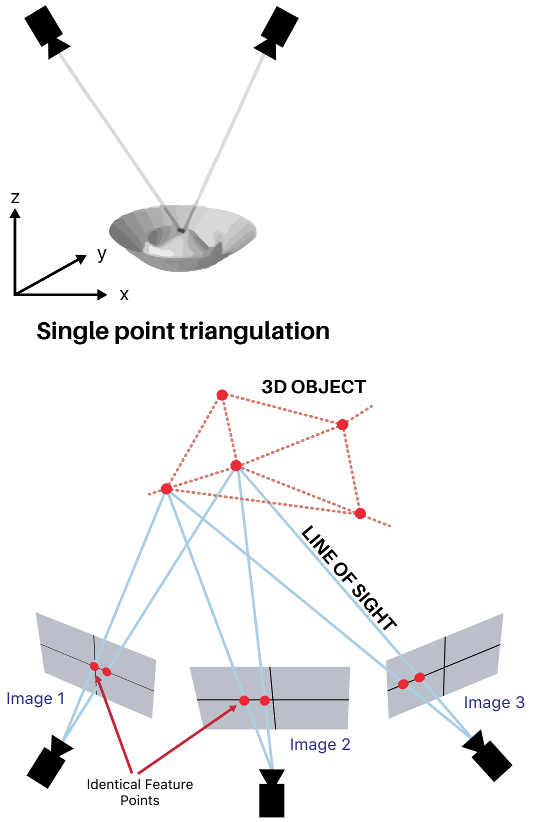


Fig. 1.10: By finding points on the object that are present in multiple photos, the location of these points in 3D space can be calculated through triangulation.

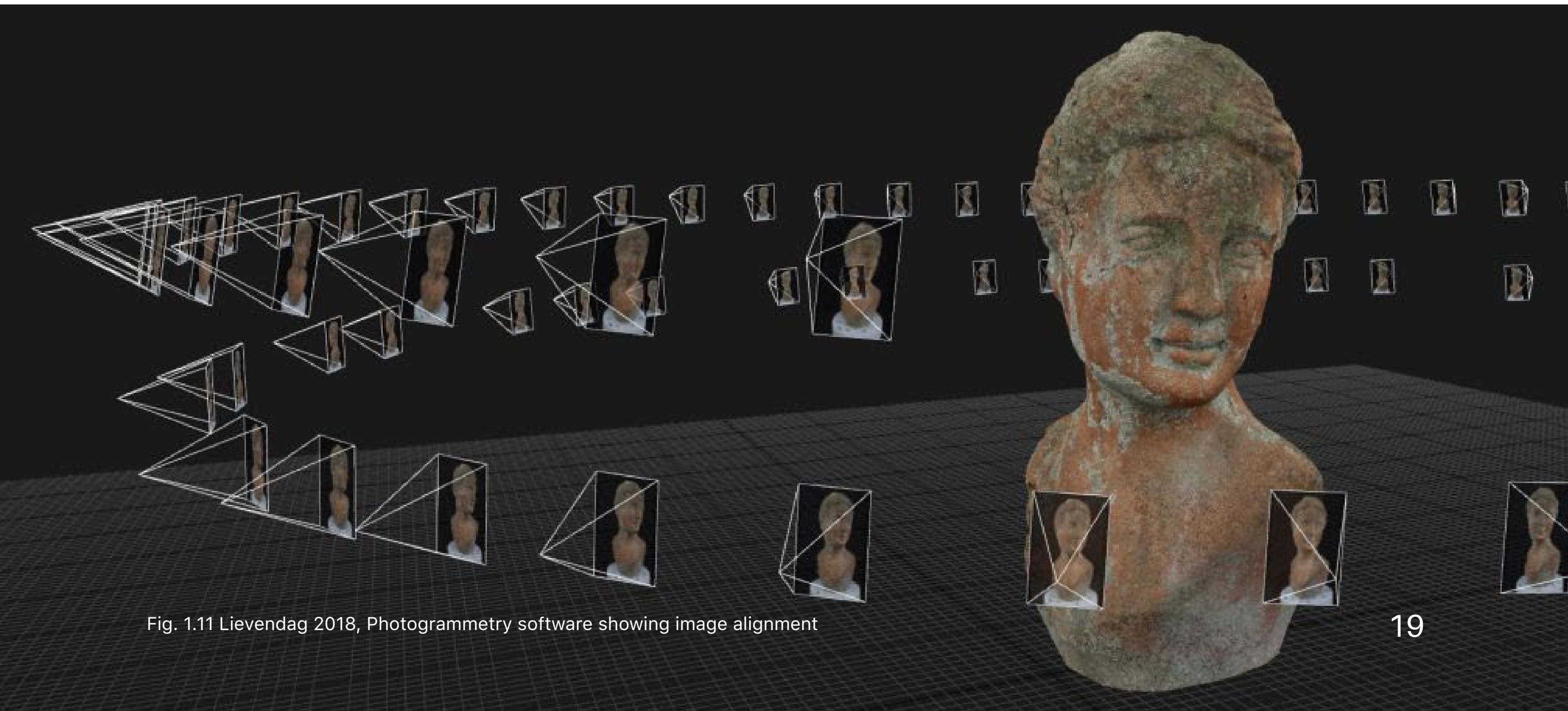


Fig. 1.11 Lievendag 2018, Photogrammetry software showing image alignment

02

EXPLORE

In this chapter

This chapters covers the insights gained from desk research. Exploring the trends and data that is available online. Reading this chapter will give you the context around the product of SeeFood.

The market analysis gives a picture of the current restaurant market and perspectives on what can be achieved there. In the trend analysis a look into the future is taken, giving a view of what changes in the world will likely have an effect on the product.

Additionally, the AR and 3D scanning market was explored in depth, taking a look where the market currently is, where it is going in the future, and how SeeFood fits in this.

Finally, the market is also explored in terms of competing products, mapping out who are the direct and indirect competitors, and which competing product categories should be closely watched.

2.1 Market Analysis

Initially, restaurants were assumed as the target market for SeeFood. To assess the value of this market, its size, growth and behaviour were analysed. During the project, other alternative markets came to attention, which will be compared to the restaurant market to assess whether a pivot should be made into those markets.

Restaurant market

To give some context on the restaurant market, the size, growth and consumer behaviours in the market are identified. These factors help determine how big a competitor is when knowing the amount of customers they have, what the market potential would be, and how consumers interact with this market. Later on during the validation phase a deeper look into the restaurant market is taken through interviews with restaurant owners.

Size

The Dutch Central Bureau of Statistics (CBS) provides data on all companies in The Netherlands. Using their freely available data the current size of the restaurant market can be determined. As of mid-2018 there are 13760 restaurants in the Netherlands (CBS StatLine, 2018a).

This number is just restaurants and does not include any other food & drink places such as pubs, café's, food trucks or ice cream parlors.

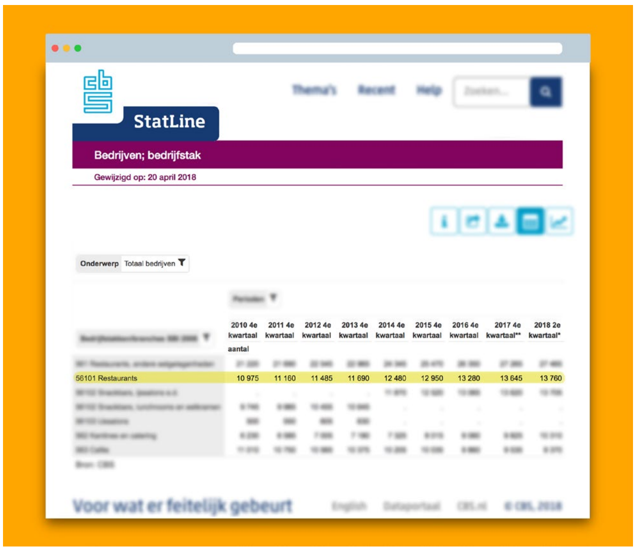


Fig. 2.1: CBS Statline data on companies

To get an idea how these restaurants businesses are performing, there is data available on revenue and cost. The newest available data for this is from 2015, where the whole restaurant market booked a €6948 million revenue and had €6199 million in costs (CBS StatLine, 2018b).

From historical data on revenue and cost between 2009 and 2015, the values for 2018 can be predicted based on historic changes.

Using these predictions and the total number of restaurants in 2018, the average revenue per restaurant is determined to be €556.411, with total average costs being €514.986 resulting in an average profit of €41.425 per restaurant.

The Dutch market is, however, just a very tiny fraction of the total worldwide restaurant market. While there are no accurate numbers on the total amount of restaurants worldwide, TheWebMinder calculated in 2014 that there would be roughly 15 million restaurants worldwide (Balcan, 2014).

Market growth

Using the same method to calculate the restaurant revenue and costs for 2018, it is possible to predict the future market growth based on the available historical data. This prediction gives a rough estimate of how the market might grow (or shrink) in the future. CBS data on number of restaurants from 2007 to 2018 and the revenue and costs from 2009 to 2015 have been used for these calculations.

	2018	2019	2020	2021	2022
# Restaurants	13.808	14.218	14.648	15.116	15.613
Revenue (million €)	7.683	8.074	8.675	9.699	11.312
Profit (million €)	572	544	536	762	1.306
Revenue per restaurant	€ 556.411	€ 567.896	€ 592.250	€ 641.646	€ 724.485

Fig. 2.2: Restaurant sector growth for the next 5 years

While the restaurant markets seems to be growing very quickly based on its historic data, there are reasons to be sceptical about this growth. It was not until 2014 that the food services market recovered from the financial crisis, which took a huge cut on their revenues as people stayed away from restaurants (FSIN, 2015). The growth will likely slow down, rather than ramp up. But with the world at risk of another financial crisis (Inman, 2018), restaurants might experience a similar dip in revenues as happened after 2008.

Consumer behaviour

Consumers' behaviour towards restaurants has been changing. Nowadays, 18% of the Dutch people eat at least once a week outside their homes at a horeca place, among millennials this percentage is the highest at 29% (FSIN, 2017). Millennials do choose for cheaper options, with an average spending of €19,42 per visit, while older generations averaging around €30 per visit (FSIN, 2017). Due to the difference in amount of visits, the total spending on horeca over a year would be similar for these groups.

Regarding technology usage at the restaurant, US company E La Carte, who produces tabletop tablets for ordering and paying in restaurants, did a research on the consumer behaviour with such a device at the restaurant table. Their study found that when using the tabletop tablet for ordering and paying the average dining time decreased by 31%, while the average spending even increased by 18% (Susskind & Curry, 2016). This study was conducted on the US market, while it shows promising results these results might not translate to similar behaviour in The Netherlands. But such an increase in spending could make it possible for restaurant owners to justify buying or leasing tablets.

Alternative Markets

When talking to customers, users, and fellow entrepreneurs about this idea, alternative markets that could be a great market opportunity for SeeFood were suggested. These markets are explained below.
These markets are compared to the initially assumed target market of restaurants using a SWOT analysis.

EXPLORING OTHER OPTIONS

While the restaurant market has shown potential to be lucrative, it is crowded with competition and restaurants can be hesitant to try new things. Therefore, it might be wise to explore other attractive market opportunities before deciding definitively which market to focus on. Below are the 3 most promising market opportunities.

HOME DELIVERY

With Deliveroo, Uber Eats and Thuisbezorgd.nl all trying to become the biggest player in the Dutch home delivery market, many of them are spending a lot of money on customer acquisition and marketing. All in order to grow the fastest, as customers are very platform loyal in this market, there is a winner-take-all dynamic (Hirschberg, Rajko, Schumacher, & Wrulich, 2016). This market consolidation is already happening as Foodora decided to cease their operations in the Netherlands due to competition (Misset Horeca, 2018). Integrating SeeFood's 3D food models within their app might be their way to market domination. Therefore, it can be a strategy to develop SeeFood with the aim of being acquired by one of these big players.

CATERING SERVICES

Big catering companies like Famous Flavours or Van Dam Catering can often get big contracts to facilitate the catering of a large corporate event. Often the C-level people (e.g. CEO, CTO, CMO) within the corporate are signing off on these deals. Most catering companies now use pictures to show what food they have to offer, so when presenting a photorealistic 3D model to clients it will give a better representation of the food, whilst also giving that 'Wow' effect. Which might be enough to convince a client to sign off on a deal.

3D MODEL ADVERTISING

The big tech companies are currently pushing hard for new 3D and AR standards. Facebook added 3D model support to their newsfeed in February 2018, and Apple released a new file format for sharing AR content in September that same year. Thus, with 3D and AR becoming more readily available on the web, it is inevitable that advertisements will start featuring interactive 3D models, making this a potentially lucrative market.
Unfortunately, other big companies are already trying to capitalize on this opportunity. As for example Sketchfab, the biggest platform for 3D models, recently started pushing their advertising possibilities (Alexeev, 2018).

SWOT Analysis

RESTAURANTS

Strengths
- Already knowledge about this market through research
- Growing market

Weaknesses
- Market is hesitant to pay for new things

Opportunities
- Increased need for automation
- Need for differentiation

Threats
- Competing startups popping up

HOME DELIVERY

Strengths
- Growing market

Weaknesses
- Not far enough in development to approach this market, SeeFood needs to be scalable

Opportunities
- There can only be one market leader
- Might acquire SeeFood

Threats
- Delivery companies might copy the idea

CATERING SERVICES

Strengths
- Market not innovative

Weaknesses
- No knowledge of catering market

Opportunities
- Using 3D models for sales pitches of big catering deals
- Partnership with big caterer

Threats
- Shrinking market

3D MODEL ADVERTISING

Strengths
- Very new market, no established players

Weaknesses
- SeeFood is not scalable yet
- No advertising knowledge

Opportunities
- New advertisement opportunity for large restaurant chains

Threats
- Big companies are already aiming for this market

In conclusion

The restaurant market, which was initially the target market of this project, has shown to be lucrative for the idea of SeeFood. However, there are many competing startups in this market and the cost of customer acquisition can initially be quite high as restaurants are hesitant to pay for new services.

Opportunities in alternative markets do not outweigh the opportunities in the restaurant market, but will remain potential pivot areas. 3D advertising will likely get crowded with competition soon, as AR experiences are becoming more popular for brands, making this the least attractive option.

The home delivery market is a huge opportunity for a big partnership or acquisition, but requires more experience before entering it. Else, a big home delivery player might build a competing product themselves.

Catering services are also an interesting opportunity, as the market lacks innovativeness and few companies are trying in innovate in this space. However, with little knowledge about the market and the market currently shrinking, it might turn out difficult to find customers.

2.2 Exploring AR

The introduction explored what AR is and how it can be experienced. This chapter will dive deeper into everything involving the AR market.
In order to get to know what the best way is to use AR in a restaurant, different devices to display it are explored. A look at how applications for AR can be developed is done by comparing the available frameworks. Lastly, the current AR usage in the market is analyzed to determine the size and impact AR application are having.

Use cases

With the promise of augmented reality comes a lot of new opportunities. The markets augmented reality likely will have an impact on are diverse. Briefly exploring these will give an idea of how big the total impact of augmented reality will be on people's lives. Nine markets where AR will have a big impact on in the future are presented in figure 2.4, giving some context for how common AR will be in the future.

AR Devices

Augmented reality is often consumed in one of two ways: Either through a regular display and camera (e.g. smartphone or tablet) or through a headset or glasses. While AR headsets or eyewear can often provide a better and more immersive AR experience, consumers might not be ready for them. For early adopters to start embracing it, the price point would need to be below €1000 according to Techcrunch (Grobman, 2017). To learn how far the development of AR headsets is, an overview of the most discussed headsets was made (see figure 2.3).
All AR headsets that are available for purchase are still priced above the €1000 mark, and all of these are still developer versions. The only exception being Google Glass, which now has a business version aimed at certain niche industrial use cases.
Within this project the focus will therefore be on smartphone or tablet enabled AR, as AR headsets are likely still years away of reaching mass market.

Magic Leap One
Status: Developer Kit (creator edition)
Price: €1975

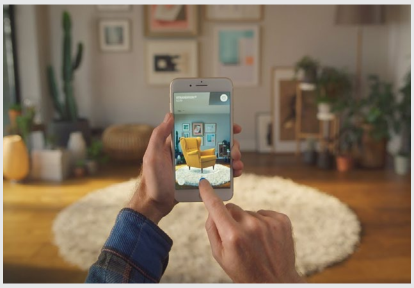
Microsoft Hololens
Status: Developer Kit
Price: €3299

Google Glass
Status: Consumer version failed & discontinued, business version now successful
Price: €1500

Vuzix Blade
Status: Developer Kit
Price: €1099

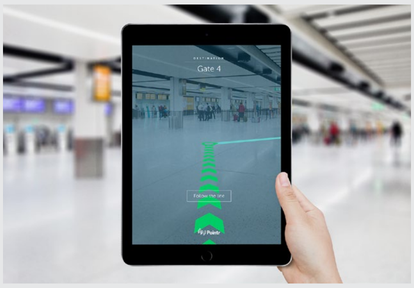
Leap Motion Project North Star
Status: Prototype
Price: Unknown, but said to be under $100

Fig. 2.3: Overview of AR headsets and glasses



Retail

AR gives the possibility for people to view products from home. Rather than seeing images of a product, people can see how a chair would look in their room, or how a clothing item might fit them as if they were wearing it.



Navigation

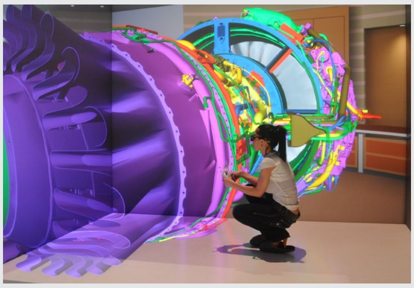
Navigation signs might become a thing of the past when everyone has personalized navigation that is shown in augmented reality, showing the user exactly how they would need to navigate to reach their destination.

Medical

One major use case within the medical world would be during surgeries, augmented reality can project the necessary extra information on the patient while still making sure the surgeon can see the real world.

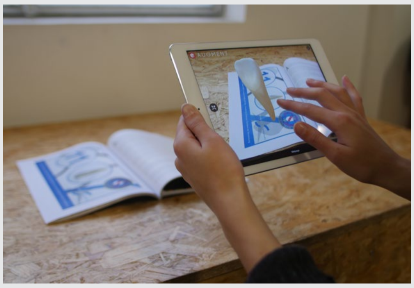
Repair & Maintenance

In an industrial environment extra information can be presented when doing repairs or maintenance. For example, seeing previous repairs, inventory information on certain parts or highlighted parts which need to be checked.



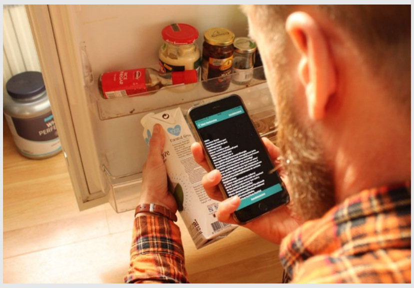
Design & Engineering

For engineers and designers working with CAD programs new possibilities to interact with these programs will arise because of AR, making it easier to orient around the object and visualizing how it would look in the real world.



Education

Some things are better explained using 3D models or animations, these can be added to certain textbook pages without the need for a fully digital book. Blending digital and physical experiences for a better educational value.



Accessibility

The ability of augmented reality devices to recognize the environment around the device through cameras opens up opportunities to use this technology for helping blind or deaf people experience what is happening around them.

Training

Being able to add instructions on top of the real world using AR allows for use for trainings. While also being able to simulate certain event, for example a fire department training using virtual flames throughout a building.

Entertainment

Having virtual objects projected into the real world gives the opportunity for more immersive entertainment experiences, making for example Pokémons come to live.

Fig. 2.4: Use cases of augmented reality

Mobile AR

Framework options

When building an augmented reality app you almost always want to use an existing library for the augmented reality functionality. Creating this yourself is nearly impossible, as it takes quite complex and optimized algorithms to track the world around you. There is no need to reinvent the wheel here.

As became clear from the technology trends (see chapter 2.4), mobile AR frameworks are hot right now. This was triggered by Apple launching their ARKit framework which contained a massively improved simultaneous localization and mapping (SLAM) technique (Tabatabaie, 2017). This technique works by recognizing high contrast points in the environment (feature points) and keeping track of their locations as the camera moves around. Depending on how their locations change relative to each other, combined with the gyroscopic data of the phone the location of these points and the camera in 3D space can be calculated (see figure 2.5) Previous technologies such as Google Tango could provide better SLAM results, but they required extra hardware and because of that only available on a very limited number of phones.

Existing mobile AR frameworks before ARKit often relied on marker based tracking, but this has the huge downside that the user would need a physical object (the marker) for AR to work. However, for the context of this project, the usage in a restaurant scenario, this is not a major downside. As a cheap marker can be placed on every table, or even a physical paper menu can serve as the marker for the AR menu.

The 5 most popular AR frameworks currently available were explored further and compared to judge which method would be best for building an AR menu app.

ARKit (by Apple)

Since: June 2017
AR techniques: SLAM, marker tracking
Compatibility: iPhones (6S & newer) & iPads (Pro 2015 & newer)
Price: Free

ARCore (by Google)

Since: August 2017
AR techniques: SLAM, marker tracking
Compatibility: Limited new high-end Android phones, and all ARKit devices
Price: Free

Vuforia

Since: 2008
AR techniques: Marker tracking
Compatibility: Nearly all phones & tablets of the last 4 years
Price: $99/month

Wikitude

Since: 2008
AR techniques: SLAM, marker tracking
Compatibility: Nearly all phones & tablets of the last 6 years
Price: €2490/year

6D.ai

Since: 2017 (still in private beta)
AR techniques: SLAM
Compatibility: All ARKit & ARCore devices (future), iPhone X and 8 (now)
Price: Not yet announced

Fig. 2.6: Overview of AR frameworks

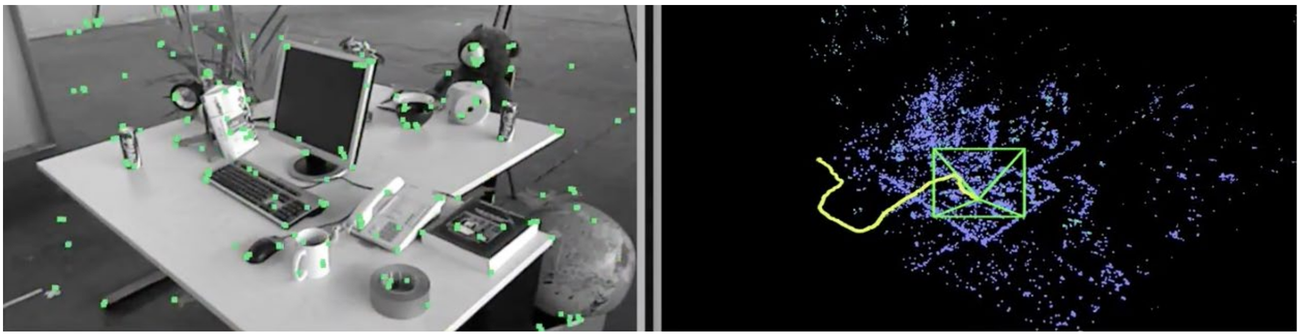


Fig. 2.5: Kudan 2018. SLAM Tracking, left: feature point detection, right: mapping these points and user location in 3D space

ARKit (Apple) and ARCore (Google) are most promising due to deep integration with the OS, while also providing radically better SLAM than what was previously available. Both are completely free to use, which is another advantage as €1000+ per year is a huge price tag when starting to develop an app.

While Apple beat Google to market by announcing ARKit available a few months earlier, there does not seem to be much difference now in whether one is better than the other (Blum, 2018).

A company to watch for the future would be 6D.ai. While they're still in beta their product offers some unique tech that ARKit and ARCore do not do, such as occlusion (i.e. virtual objects are invisible when behind real objects) and they're aiming to build the AR Cloud. It is built on top of ARKit, but uses its own algorithms developed in the Active Vision Lab of Oxford University.

Availability

While ARKit and ARCore provide the best possible AR experiences, the devices they're compatible with are limited. This is due to the calculations being very processor intensive. Therefore, if consumers were to use an AR app on their own devices, a large part of them would be unable to do so.

ARCore is compatible with Apple iOS devices, but this compatibility is limited to Cloud Anchor support, and for the AR tracking the iOS device would need to rely on ARKit.

Currently ARKit is more widely available than ARCore, this is due to both camera calibration and processing power that is necessary for mobile AR. As Apple builds both the hardware and software and even builds their own mobile processors, they have a huge advantage in making these technologies work seamless together. Current estimates predict there will be 600 million ARKit compatible devices by the end of 2018 (Merel, 2017). This number is rapidly growing due to average consumers upgrading to a new phone every 2 years, That number is predicted to grow from the mid-2017 estimate of 380 million ARKit devices (Boland, 2017). With the total amount of iPhones being 715 million in December 2016, and expected to grow to 880 million by the end of 2018 (Reisinger, 2017), around 70% of all iPhone users will be able to use ARKit by the end of 2018. ARtillry expects that by 2020 the amount of non-ARKit iPhones to be negligible.

ARCore, however, has the most potential to become the biggest platform in a few years time. While it is estimated ARCore was available for around 100 million devices in February 2018 (Amadeo, 2018), the market share of Android devices (ARCore devices) is much bigger than iOS devices (ARKit devices), with Android phones having a worldwide market share of around 75% and Apple iPhones only 20% (StatCounter, 2018)

Looking at the Dutch market, this distribution is quite different, with 61% Android phones and 37% Apple iPhones (StatCounter, 2018). Especially among Dutch centennials and millenials there is a strong growth in iPhone usage, with 52% of centennials having an iPhone at the end of 2017 (Telecompaper, 2018). These younger generations might be the most interesting target group, as they are the most open towards using new technologies and visit restaurants more often than older generations.

At the end of 2018...

ARCore

70%
iPhones support ARKit

10%
Android phones support ARCore

37%
Dutch people have iPhones

52%
Dutch centennials have iPhones

* All these percentages are estimates based on research done by ARtillry (Boland, 2017), ARS Technica (Amadeo, 2018), StatCounter (StatCounter, 2018), and Telecompaper (Telecompaper, 2018)

Tablets

With roughly only 1 in 3 Dutch people having a phone that can run ARKit or ARCore now, it is not suitable yet as a complete replacement of a menu. The idea of having tablets available at the restaurant as menus could therefore be an interesting (temporary) solution.

Looking at the possible AR frameworks, ARCore does not support any tablets yet, while ARKit is available on a limited number of relatively new iPads. While ARKit is free to use, it does require expensive hardware that restaurants would need to buy or lease iPads for it. Both those options become very expensive unfortunately.

The cheapest iPad that supports ARKit currently costs €300 (excl. VAT), but that model still features a sub optimal camera that might struggle with AR in dimly lit environments, such as at a restaurant. Even if restaurants were to supply 1 tablet per table, a medium size restaurant would then still need around 20 tablets. This calls for an upfront invest of €6000. Restaurant likely are not going to invest such money.

Comparing a few leasing companies in The Netherlands, the cheapest option for this same model would cost €20/month for a minimum lease period of 24 months (iPadshuren.nl, 2018), bringing the total cost to €480. This is without the possibility of salvaging part of the costs by reselling it, as a 2 year old iPad would still resell for over 50% the original retail price. Making leasing in the long run more than twice as expensive.

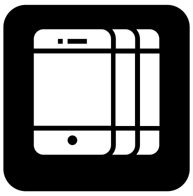
It is unclear why all leasing companies are so expensive, but with the good salvage value of iPads, it would also be a possibility that SeeFood facilitates the leasing. This would require a big financial investment for every new restaurant, thus requiring seed capital from investors in order to finance such a possibility.

It is worth considering if AR is necessary, as it would also be possible to go the non-AR route with simply showing 3D models the user can interact with, in that scenario a €100 - €150 Android tablet would be sufficient, reducing the potential costs of buying tablets by 60%.

Next to the lack of AR functionality, these tablets would also have lesser display quality, performance and battery life. In order to know if this tradeoff is worth the cost savings, interviews with restaurant owners and testing AR with visitors would need to be conducted.

Limitations of mobile AR

Even for those devices that do support new mobile AR frameworks, the technology itself is far from perfect. While many believe that AR is at a point now that it is ‘good enough’ to have meaningful applications and gain popularity, many issues and annoyances would ideally still need solving. To highlight the biggest limitations:

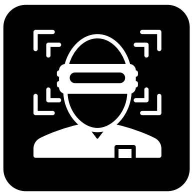


Compatibility

As previously pointed out, few devices currently support the latest AR frameworks. And it likely will take a few years until this is redundant.

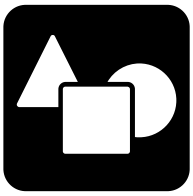
Tracking not flawless

AR tracking is still not perfect, sometimes objects can vibrate, drift away, or float above the ground. It also fails with too little ambient light.



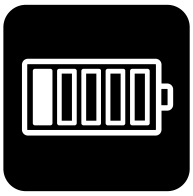
Immersion

Mobile AR is limited to the screen size of your device, limiting immersion by only taking up a small part of your vision.



Occlusion

Current AR frameworks lack proper depth sensing, therefore they are unable to occlude virtual objects behind real world objects.



Battery drainer

With constant camera usage in combination with high processor usage, AR apps will very quickly drain the battery of the device.

Problems such as compatibility and imperfect tracking will likely be solved in the next few years. Similarly for occlusion, but a solution to that is now already possible with the 6D.ai framework, although it is not perfect yet. Immersion and battery drainage are harder to solve. Immersion will be much improved with AR glasses when those become common. Battery drainage can only be slightly improved with new hardware, but with wireless charging being more available this is less of an issue.

AR Usage

When Apple's ARKit was hyped to be a big innovation, lots of ARKit applications were expected to launch on the App Store in the next year. However, this did not happen (Miller, 2018). One reason might be the lack of AR Cloud support for current AR apps (Miesnieks, 2017). What the AR Cloud is can be read in chapter 2.4 'Trend 7 - AR Cloud'. Another possible reason for this might have been the state of the entire AR market at this moment.
Consumer expectations are at an all-time low according to Gartner (see figure 2.7), people have seen some AR drawbacks a few years ago: Google Glass, which got horrible media attention due to privacy problems for people, pokemon go (which was not impressive in terms of AR), or older version of layar, blippar, etc. which only contained spatial or 2D AR.

While it might seem paradoxical, this point where expectations are at an all-time low is actually a great moment to start a startup in such an area. The best phase to invest in an emerging technology is during the 'Innovation Trigger' phase followed up by the 'Trough of disillusionment' phase (Peterson, 2018).

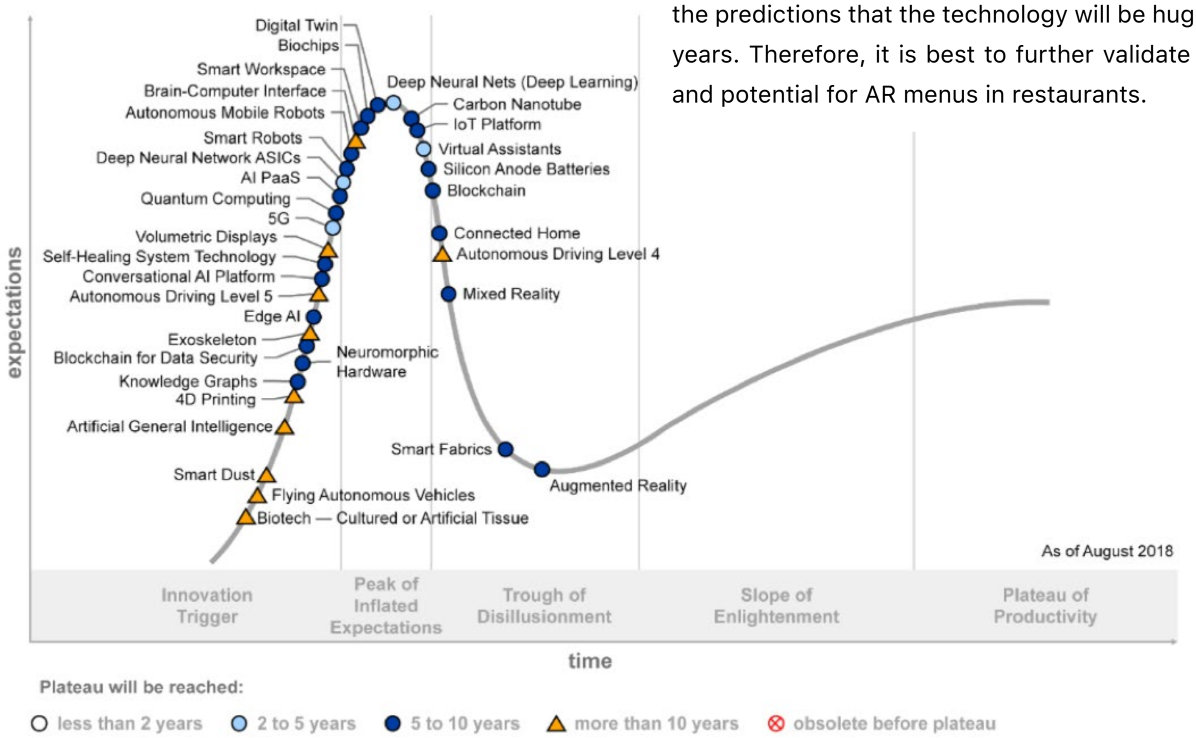


Fig. 2.7: Gartner 2018a, Gartner Hype Cycle as of August 2018

In conclusion

It is still the early days for this new wave of mobile augmented reality. There is a huge potential for what AR can become, with many potential use cases. Whether this is the perfect solution for restaurant menus is still debatable. There are benefits for using AR is this context, but we are still a few years away before a big majority of the consumers own AR compatible phones. So the only way to truly replace the menu with an AR menu, would be for restaurants to have a tablet on each table. Those are, however, very expensive. While consumer spending was proven to increase when a restaurant had tabletop tablets (Susskind & Curry, 2016), it is uncertain whether this would be similar in The Netherlands, and if restaurant owners would want to take that risk. Further interviews with restaurant owners should clear this up.
While AR does not sound attractive, it is either too expensive buying tablets or too early for consumers to bring their own phone to the restaurant, both these issues will decrease over time. As of now, Apple's ARKit with support for 70% of all iPhones would be the best AR option for a first version of the app, as it could potentially reach the most people. As prices for tablets drop and people upgrade their phones. AR is at a stage now where it would make sense to invest in it, betting on the predictions that the technology will be huge in a few years. Therefore, it is best to further validate the need and potential for AR menus in restaurants.

2.3 Exploring 3D Scanning

Chapter 1.5 explained briefly how photogrammetry works, however, there are more techniques for turning a physical object into a digital 3D model. Other than recreating an object using CAD, this chapter focuses on 3D scanning methods. What are the possibilities, how are these techniques used, what scanners are available, where is this market going in the future and linking these factors to how 3D scanning should be done for SeeFood.

Scanning methods

There are 4 main types in which 3D scanning can be categorized. These are: contact scanning, laser scanning, structured light scanning, and photogrammetry. Each method comes with its own advantages and disadvantages. In order to assess which method is most suitable for scanning restaurant meals, each of these methods had been explored.

Contact scanning

Using a mechanical probe this scanner will gently touch the object all around and record the contact points digitally. While this method was commonly used in the past, it is now often replaced by laser or structured light scanning due to the fact that it could damage or alter object by touching it, and scanning is slow compared to these other methods. In certain specific applications where consistent repeatable measures are necessary (such as quality control) this method is still used. For scanning food items this technique is unusable, as touching some types of food would likely deform or stick to the probe.

Laser scanning

A laser beam is projected onto the object. When this beam reflects back onto the sensor of the scanner it can measure the distance based on the time it took for the laser light to travel. This is the most commonly used method of laser scanning and also called time-of-flight or LIDAR.

Laser scanning can be seen as the industry leader in the global 3D scanning market with over 50% of the total market revenue (Grand View Research, 2015).

Laser scanners are great for their speed and long-range possibilities, however for laser scanners with good accuracy the cost can often run in the tens of thousands of euros.

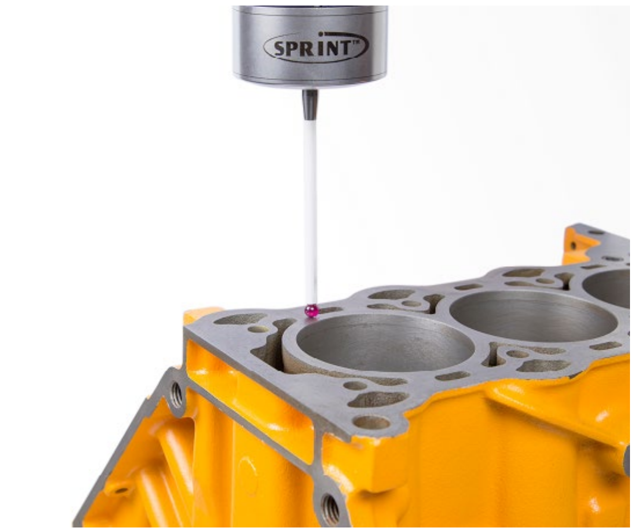


Fig. 2.8: Contact 3D scanning with a Sprint probe

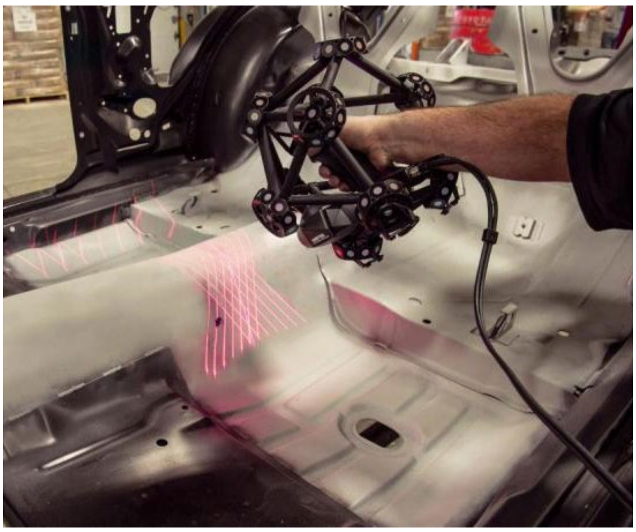


Fig. 2.9: Laser Scanning using a handheld laser scanner by CreaForm

Structured light scanning

Using some sort of projector the scanner will project different patterns of light onto a subject, quickly alternating between the patterns and taking photos of each projection. Based on how each pattern warps around the object the geometry of the object can be calculated.

Often used types of structured light scanners are white light or blue light scanning. But it does not necessarily have to be visible light, as for example Apple's iPhone X's TrueDepth camera projects an infrared dot pattern and uses an IR camera to capture how the dot pattern is warped.

This method is best used for small and close-range objects, as the light becomes increasingly dim the further it travels and would thus require a stronger projector. The ambient light also cannot be too bright compared to the projected light in order to ensure the camera can still recognize the pattern. These scanners are moderately expensive and cost a few thousand euros.

The need for little ambient light might be a problem when used for food scanning, as food photography generally needs perfect lighting conditions (discussed in chapter 4.2). The projector light is likely used to illuminate the subject for to photographs used as texture. Whether that would suffice should be tested with such a scanner.

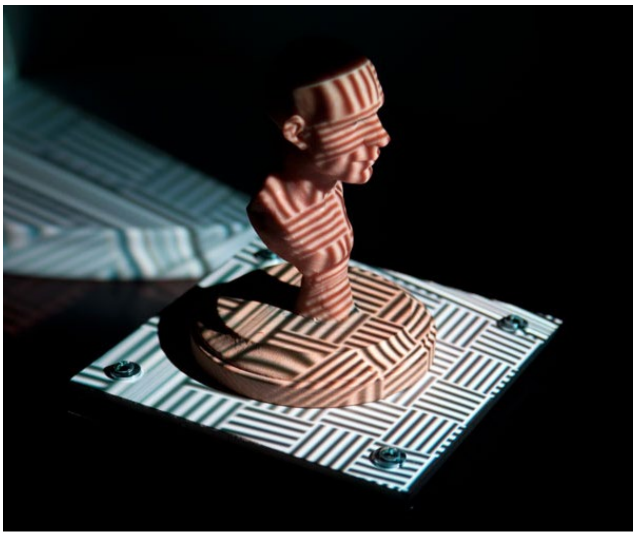


Fig. 2.10: Structured light scanning using a white light projector

Photogrammetry

Using photographs taken all around an object, it is possible to recognize feature points (contrasting pixels) in these photos. Matching these points between photos, it is possible to calculate the camera locations and reconstruct the 3D geometry of the object. Adding the photos as a texture makes the model look photorealistic.

Photogrammetry generally has a low accuracy, increasing the amount of photos and quality of the photos can improve this but it likely still will not match other 3D scanning methods. A big advantage is that the aligned photos around the object can be applied for a photorealistic texture. This can mask small accuracy visually. However, for other scanning methods it is also possible to take additional photographs and apply them as a texture. Some other scanners even include a photo camera to take pictures in between the scanning process. To see how these compare to a photogrammetry process, a comparison with a structured light scanner was made in chapter 4.1.

The main advantage is that this can be by far the cheapest way of 3D scanning. If the object does not move, using only 1 camera can be enough. With the increased quality of smartphone cameras, people are likely already in possession of an adequate camera for photogrammetry.

Fig. 2.11: Photogrammetry using a full-body capture rig

Existing scanners

Next to different types of scanning techniques there are also many different types of scanners. There are not any predefined categories for this, so by analysing over a hundred scanners available on the market, six categories were derived from that.
Each of the categories has been evaluated which of the four scanning techniques are commonly used in this scenario and marked with their respective icons.
Each category features a short description of how the category is defined, and two existing scanners that fit in this category are given as examples.

An interesting insight is that there seem to be hardly any photogrammetry scanners in the medium price range, so desktop and handheld scanners. For scanning small to medium sized objects using photogrammetry, people are forced to use either smartphone apps or manually take photos and process them in some photogrammetry software.
A photogrammetry scanner in these categories would be ideal for food scanning, as it could provide the necessary quality and consistency needed for getting good results. The lack of such a product also could be an interesting market opportunity to develop this, as more industries other than food could benefit from this. Think of a retailer like Amazon or Coolblue wanting to showcase all their products as 3D models for example.

Scanbox

Big scanners that encompass the whole object in a closed off scanning environment. This type of scanner seems to exist for every type of scanning technique and is often the most expensive solution.

Tripod 3D scanners

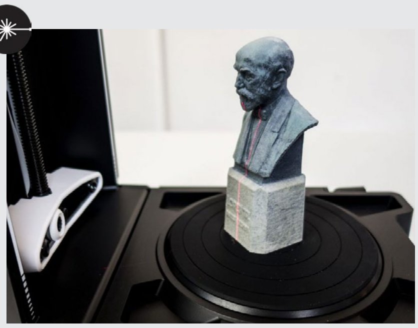
These scanners are characterized by the need to put them on a tripod. This allows the scanners to be easily moved to a new location, however they should be completely still during the scanning process.

Desktop 3D scanners

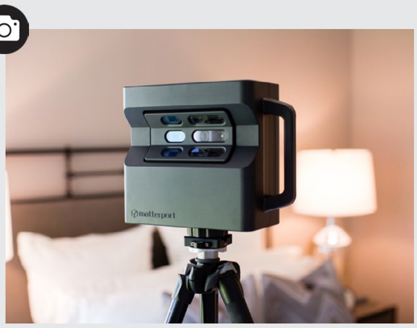
Scanners that would fit on a person's desk, suitable for scanning small to medium sized objects. They feature a turntable and often only 1 camera, projector or laser.

ATOS Scanbox 5120 Structured Light Scanner

FARO Focus 3D X laser scanner


Matter and Form 3D Scanner V2 laser scanner


3DCopySystems Big Alice photogrammetry rig


Matterport Pro 2 photogrammetry scanner


HP Sprout 3D structured light scanner

Photogrammetry Software

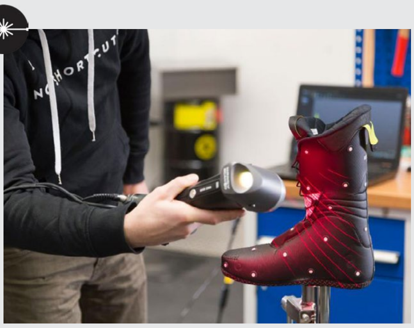
In contrast to the other scanning techniques, photogrammetry scan solutions often do not give you a 3D model automatically. For that you would need to rely on smartphone scanning apps or automated scripts. Else, you would still need to take an extra (manual) step to convert these photos into a 3D model using photogrammetry software. An exploration of the available software options and mobile apps for photogrammetry is described in chapter 4.1.

Use cases

In order to also get an idea of how widespread 3D scanning usage is and in which markets it is used most commonly used, 9 use cases of 3D scanning have been elaborated on the next page in figure 2.12. Traditionally 3D scanning was mostly used in engineering and manufacturing environments. However, as costs of 3D scanning decreased thanks to cheaply available qualitative cameras (as commonly found in smartphones), 3D scanning is becoming available for consumers and small businesses, thus creating new markets.

Handheld 3D scanners

These scanners can be held by hand where the user is required to move around the object to scan. These are often tethered to a laptop or a desktop pc to give real time feedback of how the scan is going.


CreaForm HandySCAN 3D laser scanner


Artec EVA white light scanner

Attachment 3D scanners

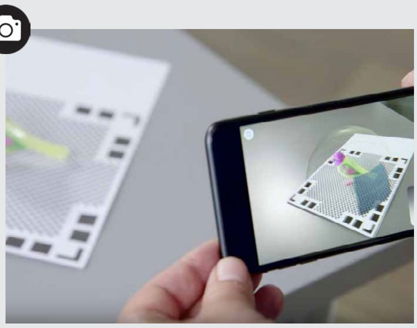
These scanners require a connection to another device to process the data, and can be distinguished from handheld scanners by their price being significantly cheaper and quality-wise worse results.

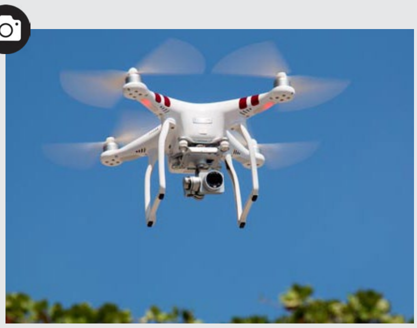

Bevel 3D phone attachment laser scanner


Structure Sensor structured light scanner

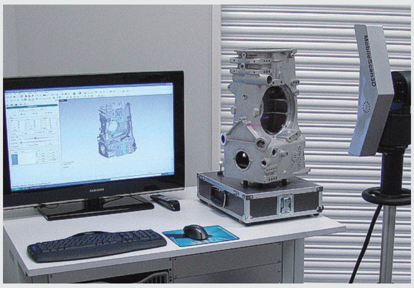
Photo cameras

While photo cameras are used for taking photos and videos, these devices can be used for 3D scanning if you take the right photos. Every product with a camera not made for 3D scanning fits within this category.

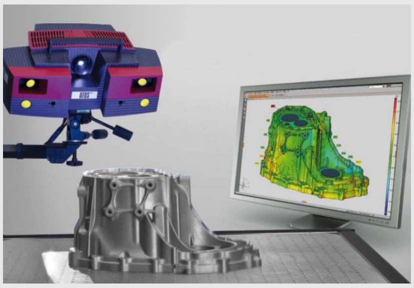

Qlone app, phone camera photogrammetry


DJI Phantom 3 drone photogrammetry

Use cases of 3D scanning



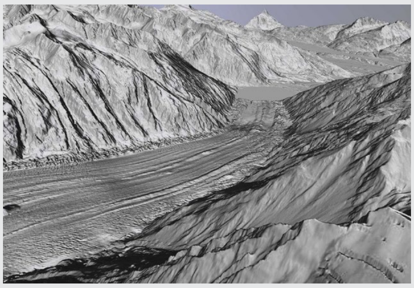
Reverse Engineering
When wanting to recreate the exact geometry of a physical object 3D scanning can offer a quicker solution over manually measuring and recreating the object.



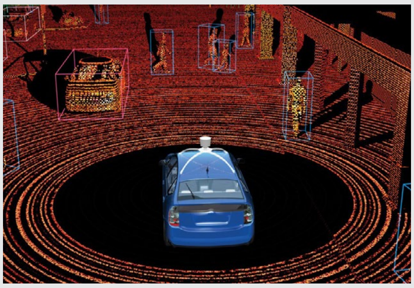
Quality Control
For industrial inspections to see whether produced parts match fit within the allowed tolerances 3D scanning can quickly compare the part to the original CAD model.

Healthcare
To create custom fitting healthcare products, such as orthotics or prosthetics, 3D scanning offers the possibility to recreate the exact geometry of an individual's body.

Archeology
To preserve or inspect archeological sites laser scanning or photogrammetry is used to capture the geometry and appearance.

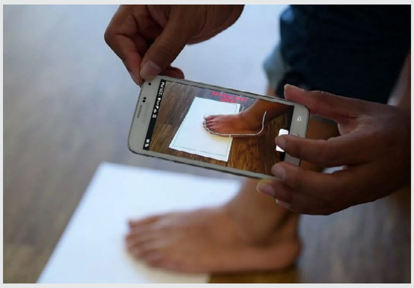


Geology
Topographic maps can be created using a long distance laser scanner, or for hard to reach locations by flying around a drone equipped with a laser scanner or photo camera (photogrammetry).

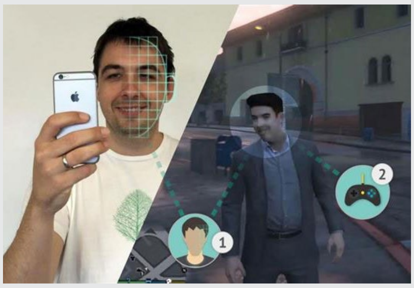


Autonomous vehicles
Autonomous vehicles need to be aware of the rough 3D geometry of their environment to recognize threats and prevent collisions. Laser scanning is hereby used to accommodate this.

Real Estate
To give virtual real estate tours it is possible to recreate an entire house using photogrammetry. For example the startup Matterport has created a scanner to automate this process.



Fashion
The fashion industry is embracing 3D scanning solutions to enable size-recommendations or custom made to size fashion items, especially for shoes this has became popular in the last years.



Entertainment
The entertainment industry uses 3D scanning for example to convert actors into game models or for usage in special effects. In the future when smartphone 3D scanning becomes good enough this will likely be used for customized entertainment.

Fig. 2.12: Use cases of 3D scanning

New developments

While there are not that many technological breakthroughs in 3D scanning technologies, there are still a lot of new developments in this market due to faster computers.

Depth sensing cameras in phones

Smartphones are starting to get depth sensing cameras. While initially not meant for 3D scanning, but for biometric verification or augmented reality applications, developers are able to utilize these cameras for 3D scanning purposes. Two examples of this are the Scandy app and the Bellus3D app, both for iPhone X.

Real time photogrammetry

Photogrammetry is computationally very demanding and even at low quality settings it used to be impossible to render the results in real time. However, with the speed of the current generation of processors in iPhones developer Tim Field was able to create a demo that does realtime photogrammetry (Field, 2018), albeit at a low quality. These real time results are however a great way to visualize which spots on an object are not rendered properly and thus need more photos. After getting the right photos, a high quality model can be recreated later.

Video photogrammetry

With the increase of computation power in phones and cameras it became possible to shoot video in 4K in the last few years. At this resolution the video frames retain enough detail that they would be acceptable to use them as photos for photogrammetry. The benefit of this is that taking a video of all angles around the subject will be significantly faster than taking photos.

Machine learning

Machine learning is still an increasing trend, as also becomes clear in the next chapter, which has created some algorithms that are trained at recreating 3D models from photos. While still early research, one study shows incredible potential of a computer recognizing the 3D geometry of an object from a single 2D photo after being trained on the generic shape of this type of object (Wu et al., 2016). Similar to how a human could understand the 3D geometry of a chair when only shown a single photo. This could prove useful in the future to automatically fix mistakes a photogrammetry algorithm might make.

Fig. 2.13: Wu et al., 2018. Neural network trained on chairs guessing the geometry of the chair on the left based on this single photo.

In conclusion

The 3D scanning market is rapidly evolving. Especially mobile photogrammetry still seems immature and will likely change drastically over the next couple of years.

The trend of mobile augmented reality will likely accelerate this growth, as the SLAM technology used in augmented reality can provide a basis for better smartphone photogrammetry.

Specifically for SeeFood both the technologies of structured light scanning and photogrammetry seem most interesting, as laser scanning seems too expensive and contact scanning would not work. A comparison between these two technologies will need to be made to determine which is the best fit for this project. On paper, structured light scanning is more expensive but provides the benefits of instant results and better scan accuracy. However, for food the most important aspect is visual realism, which is compared in chapter 4.1.

2.4 Trend Analysis

The trend analysis focuses on a wider scope of the relevant markets. Looking at the horeca and technology sector, as well as consumer trends. While some overlap with the market analysis, the trend analysis looks mainly into what can be expected in the future. The most relevant trends that have been discovered are listed below.

Horeca Trends

While chapter 2.1 explored just the Dutch market, for the trends a global look at what shifts are happening in the food services industry is taken. The defined trends in this chapter are likely to have big impact on the worldwide food services industry in the next 10 years.

TREND #1 - Robot restaurants

Robotic restaurants are on the rise. Humans are slowly becoming obsolete for a lot of tasks and are being replaced with cheaper machines (Cross, 2017). This trend has been going on for years, but this year it caught up to the restaurant industry. The first robot restaurants like Spyce and Creator opened to customers in 2018.

As for whether consumers like this trend of automation the responses are mixed. Mindshare conducted a study on people's opinion towards automation. 54% of the respondents would choose the quickest and most convenient option when presented a choice between a robot and a human (Mindshare, 2018). Especially among the younger generation (18-24s) the preference of interacting with a machine was the highest. Their research also found that people want to have control over their interaction, deciding whether they wanted to interact with a human or a machine. Machine interactions that provided more choices than that were otherwise available proved to be more popular, such a being able to choose your exact airplane seat. For SeeFood this trend could represent an opportunity to automate the ordering and paying process by enabling customers to do this on a tablet menu or through their own phone. Restaurants who aim to attract a younger audience would be the best fit for such a proposition, as customer acceptance will likely be highest among their visitors.

Fig. 2.14: Burger robot restaurant Creator has a fully automated machine that prepares burgers

TREND #2 - Emerging tech in the food industry

Emerging technologies like AR, VR and MR are being put to use in the food industry (Bompas & Parr, 2018). The most applications of these technologies were in the areas of human resources, customers experiences, and food products (Dorsey, 2017). Many applications involved branding, where brands build a VR experience around their product showing these experiences to people at events. Looking at the usage of emerging tech within restaurants it is mainly used around building experiences. For example, the company Skull Mapping build a dinner show concept where guests are shown a story through projections on their table (see Figure 2.17).

A look into how emerging technologies might be used in a futuristic food context is given by Project Nourished. This is a gastronomical virtual reality experience, aiming to simulate all the senses of an eating experience. Using among others a virtual reality for visual stimulation, an aromatic diffuser to dissipate a certain smell, and even a bone conduction transducer to mimic the sound your chewing would make. All this technology of Project Nourished combined would make it possible to eat something without ingesting any calories, or eat things which cannot exist in the real world.

Fig. 2.15: Project Nourished, a gastronomical virtual reality experience

Lastly, another emerging technology that has been slowly gaining attention in the food industry is 3D printing. In 2014 the first 3D printer for food was introduced by 3D systems and in 2016 Food Ink was opened, world's first restaurant serving 3D printed food (see Figure 2.16). 3D printing makes it possible for new creative food shapes to be produced, automate the cooking process, make personalized meals and in a very futuristic scenario might even completely replace a chef (Chadwick, 2017).

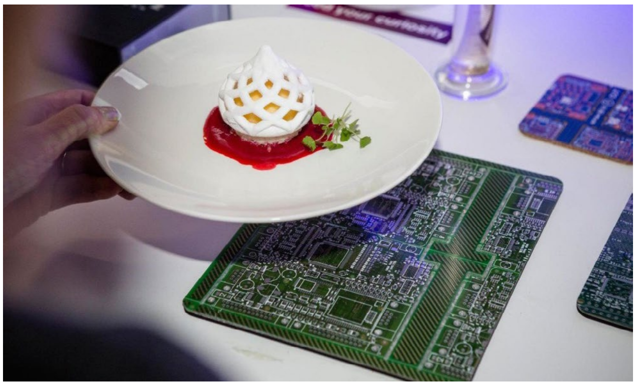


Fig. 2.16: Food Inc, World's First 3D-printing restaurant

Fig. 2.17: Le Petit Chef, an animation projected in augmented reality on a dining table

TREND #3 - Ordering apps

Many restaurant chains have launched mobile ordering apps recently, mainly quick-service restaurants. Business Insider Intelligence predicts a compound annual growth rate of 57% through 2020 (Green, 2018). This new wave of apps are more than the coupon-code apps which were popular a few years ago. These new apps have full ordering capability making it possible to have a meal ready when you arrive, enable you to save your preferences, and have an integrated loyalty system. This is still mainly done by big chains, who have the money to produce an app for their brand. This trend is increasingly becoming available to smaller restaurants too through white label order-ahead apps, as for example developed by Apptizer.

Chipotle shared some insights on their app usage and found that it most popular among millennials and centennials (Wilson, 2018). This is similar to findings from Mindshare discussed in trend #1, that those generations also had the highest preference of interacting with a machine over a human. The idea of turning SeeFood into an ordering app derived from that trend is further confirmed by this trend.

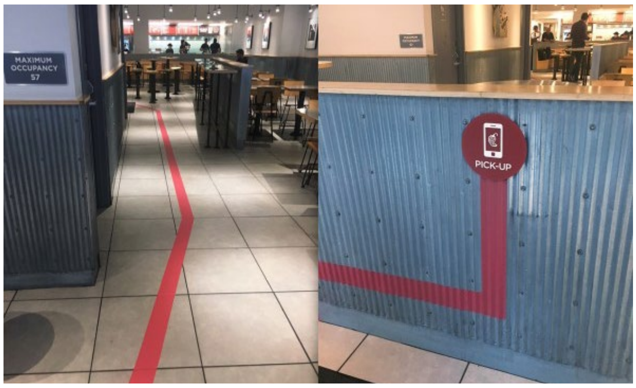


Fig. 2.18: Chipotle in-store pick-up for app orders

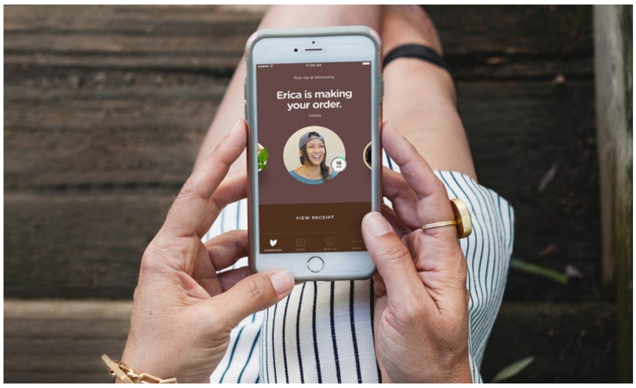


Fig. 2.19: Philz Coffee app showing order status

TREND #4 - Ghost restaurants

With the increasing popularity of food home delivery, a new type of restaurant is emerging: The ghost restaurant. These restaurants do not have tables or chairs but only a kitchen. For customers they only exist within food home delivery apps such as UberEats or Deliveroo.

These delivery companies are more than happy to stimulate this trend. With for example Deliveroo in The Netherlands having sea containers converted into kitchens made available for interested restaurants (Jalta, 2017), and UberEats approaching local restaurants to operate as a new ghost restaurant when their data analysis discovers a high demand for a certain cuisine (Chibber, 2018).

Fig. 2.20: "Green Summit runs 9 different delivery-only restaurant concepts out of one storefront in Chicago."

Tech Trends

Looking at trend reports from big consultancies and innovation firms as among others Fjord, Frog Design, Gartner, JWT Intelligence or Mindshare, the trends that overlap within a relevant context are clustered into new technological trends. Next to these trend reports, new startups and announcements of major tech companies are also considered when defining these major trends.

TREND #5 - Mobile AR

If there is one trend to be certain about this year, it is the increased attention on mobile augmented reality. While the start of this trend in mid 2017 sparked my interest towards doing a graduation project involving mobile AR, it was not until 2018 that this trend started to really take off. Nearly every 2018 technological trend report mentioned this trend as taking off in this year.

This trend was started with Apple's announcement of ARKit, where from one day to the next Apple created "the largest AR platform in the world" (Apple, 2017, 1:28:15). Google quickly followed a few months later with their direct competitor, ARCore. Google was already busy in the AR space with Project Tango since 2014, but this platform required extra sensors on devices. These were too expensive for most phone manufacturers, resulting that Tango phones or tablets never became mainstream. After the release of ARCore, Google decide to shut down their Project Tango efforts (Kastrenakes, 2017).

Other big tech companies like Facebook and Snapchat both also announced in 2017 their own AR platforms for use within their apps, Facebook Camera Effects and Snapchat Lens. All of these big AR platforms went live to the public around late 2017 to early 2018. Resulting in a huge wave of new AR apps becoming available to the public, which become increasingly available to new people as they upgrade their devices to AR compatible phones or tablets.

EMarketer believes augmented reality will go mainstream in 2018 (eMarketer, 2017), while experts from Mindshare believe that 2018 is a key milestone in AR's development from a niche to mainstream, but expect that truly mainstream adoption will likely follow in the next few years (Mindshare, 2018). Tim Cook, CEO of Apple, even calls AR "a big idea like the smartphone" (Phelan, 2017), given the possibilities of what AR could do to improve people's life. Frog Design believes that the fact that these new AR apps are becoming a shared experience for users is going to make it mainstream, where historically AR has been a solitary experience (Frog Design, 2018).

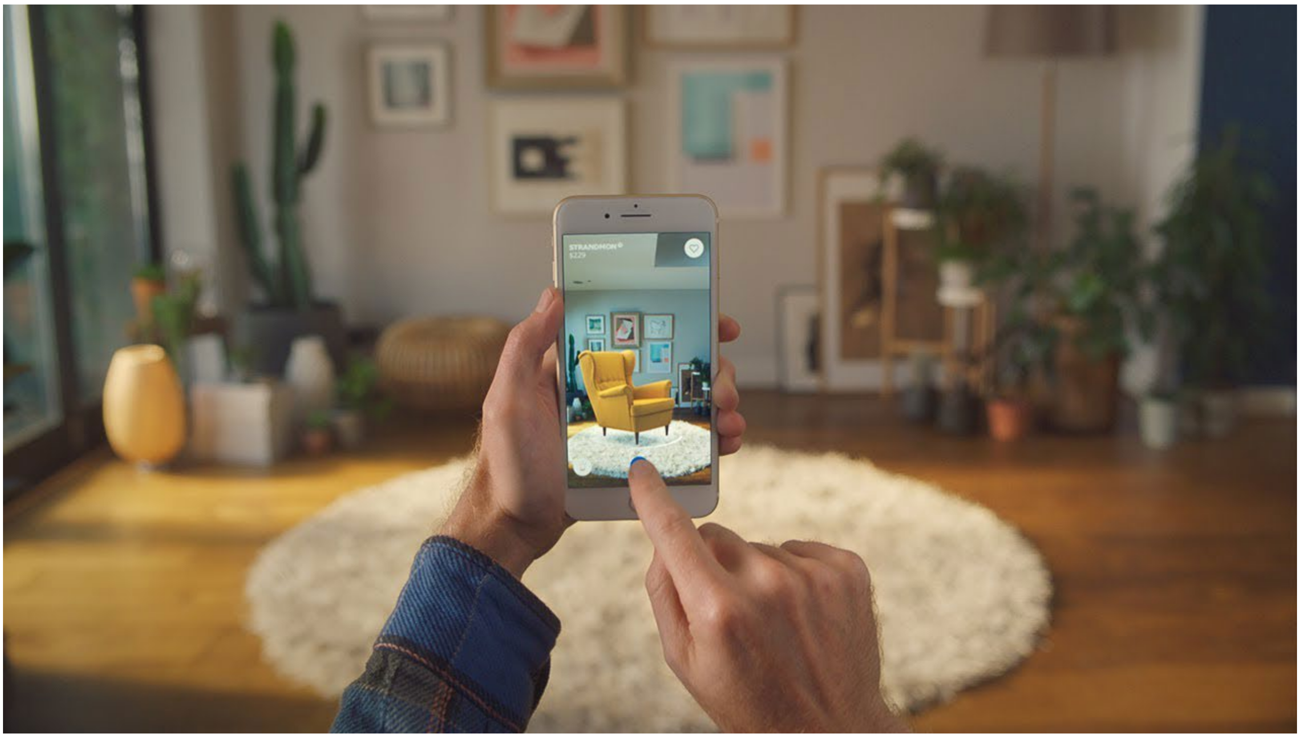


Fig. 2.21: Ikea Place app, making it possible to see Ikea's catalogue products in augmented reality in your home

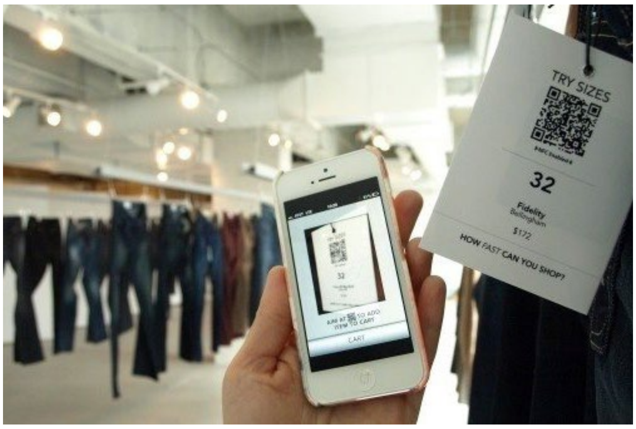


Fig. 2.22: Hointer lets customers get stock information using QR-codes

TREND #6 - Blending Digital & Physical

Digital and physical products are increasingly becoming one (Fjord, 2018). While augmented reality and mixed reality are two major examples of this, the ever-increasing amount of Inter of Things (IoT) devices is also contributing to this trend. More and more everyday devices are getting an internet connection and sensors to read their environment. This adds new features to existing devices and stimulates the possibility of automation through smart monitoring these devices, contributing to Trend #1.

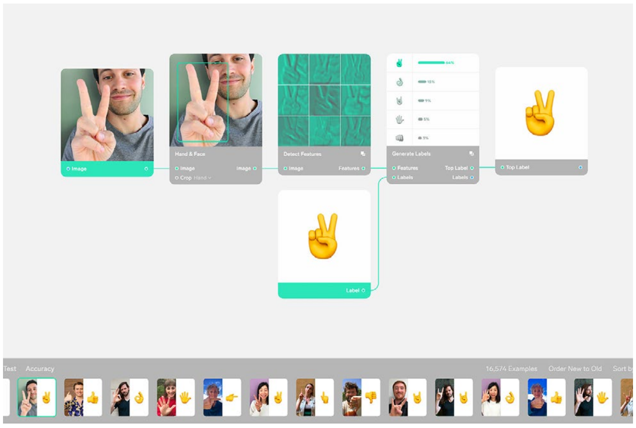


Fig. 2.23: Lobe.ai enables everyone to create and train neural networks

TREND #7 - Rise of Machine Learning

Machine learning has been a big trend the last few years, but during the next few years year it will likely be implemented into nearly every app, application or service (Gartner, 2018b). It is also becoming increasingly more easy for non data scientists to create their own neural networks. For SeeFood such neural networks might be trained to fix mistakes in photogrammetry models, removing the need for manual labour to do this.


Fig. 2.24: Google's 'Just A Line' app using Cloud Anchors for shared AR

TREND #8 - The AR Cloud

Kevin Kelly, founder of Wired, calls it the Mesh. But is also referred to as: The AR Cloud, V-Cloud, and as The Metaverse. But what all these terms try to describe is a new major platform that does not exist yet, but is predicted to be necessary for the envisioned future of augmented reality. Kelly also sees this as the third wave of the internet (Kelly, 2018). The first wave was started by companies like Google, who brought the web together and made it searchable. The second wave was the social wave, where companies like Facebook and Twitter connected people with each other online. This third wave of the AR cloud envisions a digital copy of the real world, where location data about the real world is stored and linked to the location of augmented reality objects. Such a database would make it possible for augmented reality apps to remember where certain virtual objects are located within the real world, and enables different people to see the same virtual object at the exact same physical location. The startup 6D.ai is trying to build this 'AR Cloud' since 2017, and in 2018 Google brought Cloud Anchors to their ARCore platform to enable AR Cloud like services (Miesnieks, 2018).

As was discussed earlier in chapter 2.2 about AR usage, this AR Cloud might needed for AR apps to truly become a success and for AR to live up to the hype it created. While this AR Cloud does not exist yet, it is important to observe this trend over the coming years to see how it develops, in order to be one of first AR apps using the AR Cloud when it becomes available.

Consumer Trends

Changes in consumer behaviour can happen because of a variety of reasons. It might be due to new generations that grew up in different environments than before. For example centennials were born in a time where internet is available everywhere and anywhere, radically changing their views of the world and what they believe is important.
It might also be because of technology-push, as for example the smartphone changed how people interact with each other nowadays.
Understanding these consumer trends is important to know what your target group of consumers expects of your product.

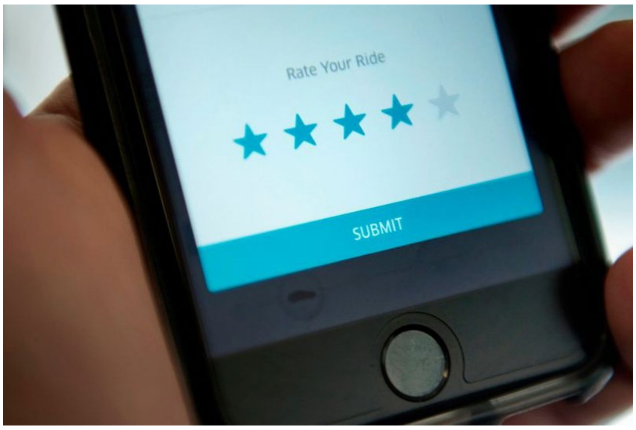


Fig. 2.25: User rating their ride in the Uber app

TREND #9 - Rating everything

More and more are consumers given the options to leave a rating on every product or service they encounter, often being able to rate a scale of 1 to 5. Examples of this are Uber or Deliveroo, where consumers are encouraged to rate the driver or delivery guy after the service.
Also with the restaurant industry this trend is catching on. In the United States two major tabletop tablet companies (Ziosk and Presto) are offering visitors the possibility to rate their waiter. But there is a negative side to this trend, managers are increasingly relying on using these ratings to determine employee performance, causing employees to only do tasks that are good for their score (O'Donovan, 2018).

TREND #10 - Experience becomes more important

Consumers are increasingly valuing the experience of all their interactions and value a good UX, with consumer spending on experiences in The Netherlands expected to grow from 15.3 billion Euro in 2017 to 20.4 billion Euro in 2025 (FSIN, 2017). As consumers value experiences more, restaurant visits are likely to increase. Making browsing the menu into a fun experience would therefore benefit restaurants in the future.

TREND #11 - On-demand economy

Consumers are increasingly expecting products or services to be available on-demand. This is especially prevalent among centennials and somewhat among millennials (Fromm, 2018). This shift is most obvious in the entertainment industry, with companies like Netflix or Spotify taking over linear TV and radio. As consumers prefer to get the specific content they want at any moment. This demand for wanting whatever, wherever, whenever will likely translate into more usage of food delivery services and more quick bites, as consumers wish to fulfil their food cravings as soon as possible.

TREND #12 - Subscription models

More companies are switching their business models from 'ownership of their product' to 'access to their product'. With this switch, also their pricing changes from a one-time fee to a recurring membership fee.

Churn rates for subscription services are high, as consumers can often easily switch to a competitor when the customer experience is not superior (Chen, Fenyo, Yang & Zhang, 2018). Among centennials and millennials brand loyalty is disappearing (Fromm, 2018), making delivering a superior experience even more important.

Because of this, subscription models are also popular among customers, lowering the barrier to try new things.

TREND #13 - Digital wellbeing

Smartphone addiction is becoming a serious problem nowadays and people are starting to realize the negative effects this constant draw for attention by their phones is having (Centre for Humane Technology, 2018). Tech companies are recognizing this consumer need for more control over their own tech usage, thus Google, Apple and Facebook have all introduced digital wellbeing features to their phones and apps in 2018.

Smartphone usage at the dinner table has long been a controversial topic, and research has shown that it undermines enjoyment of social interaction during dinner (Dwyer, Kushlev, & Dunn, 2018). This trend could therefore form a threat for SeeFood, as visitors or restaurants might not want more technology usage.

Trend Conclusions

There is a huge bet on AR by all the big tech companies. Even though Chapter 2.2 concluded the extra price for AR compatible device might not be worth it for restaurants to invest in. But with consumer availability still needing a few years, this could be seen as a bet on the future. This is similar to how the big tech companies keep investing money in their AR products while consumer engagement has been growing slowly. By focusing on AR from the beginning, the final product will be ready at the moment that the AR market reaches mass market, which is predicted to be in a few years, making it a better strategy to pivot away later if AR turns out the be a bubble, than to neglect it too soon and be behind on the competition when it becomes truly mainstream.

Within all industries (including the restaurant industry) the trend of automation is becoming more common. This would be an interesting direction for SeeFood, as the product could replace many tasks of restaurant staff. Especially ordering and paying could be done through an app, as consumers are becoming more familiar already with this style of ordering thanks to the trend of ordering apps. However, the interest of restaurants for this would need to be validated as they might be hesitant to lay off staff. Technology in general is also increasingly becoming important in restaurants. As of now this is still mostly in the form of brand experiences or exclusive restaurant concepts. Further research into how restaurants owners see technology being used will need to be conducted.

Consumer behaviour has been changing for the last few years. Especially centennials and millennials have different expectations of the world. Things need to be instant, they want to easily try out new things, and generally place a big importance on the experience of this all. While consumer behaviour has changed dramatically, the restaurant menu and restaurant experience have not. In order for restaurants to win over this new generation they will need to focus on providing a new experience.

An important thing to keep in mind here is the digital wellbeing trend. If this trend continues to grow this could result in smartphone usage becoming taboo at the restaurant table.

"We must learn what customers really want, not what they say they want or what we think they should want."

- Eric Ries, author Lean Startup

2.5 Competitors

Competition should always be expected, and rather than fearing and ignoring them you should watch them closely. By analysing your competitors thoroughly they could actually provide an advantage. Competitors likely made similar market assumptions, and based on their decisions the conclusions they've made can be derived. Competitors can also give insights into your business model, highlighting what is your unique selling point (USP) or providing a clear direction where your USP should be.
Lastly, a competitor could provide inspiration on what features the product should have and might show you how they have solved similar problems you're facing. Or as Pablo Picasso would have said: "Good artists copy, great artists steal."

Types of competition

In order to get a grip on the total competition, all competitors are classified in four different types as defined by Lehmann & Winer's Levels of Competitions Model: Product Form, Product Category, Generic Competition and Budget competition. (Lehmann and Winer, 2005)

Product form

These competitors are the most direct competition, also called brand competitors sometimes. This competition offers a similar product, with similar features and benefits and somewhat similar pricing. For SeeFood this competition would be other AR menus.

Product category

Product category competitors are still considered direct competition and include products with similar features and benefits, but they are provided in a different way. For SeeFood this would be all other menu solutions available to a restaurant, ranging from tabletop tablet menus, to plastic fake food models, but also current traditional paper menus.

Generic Competition

Generic competitors are indirect competitors. This can be described as competition in which products are used in the same context but provide different benefits. For SeeFood this would be other digital products and services that are provided to restaurants, such as POS systems.

Budget competition

Lastly, budget competition describes all products that your target customer could also spend its money on. Seeing this from the restaurant visitor perspective is the most interesting: What are the things that consumers spend their money on if deciding not to visit a restaurant?. Likely alternatives would be all other food related products and services, as people need to eat to survive it can be expected that a restaurant visit will be substituted by buying food elsewhere.

The most important competitors were mapped onto this model in different levels and further categorized into different groups.

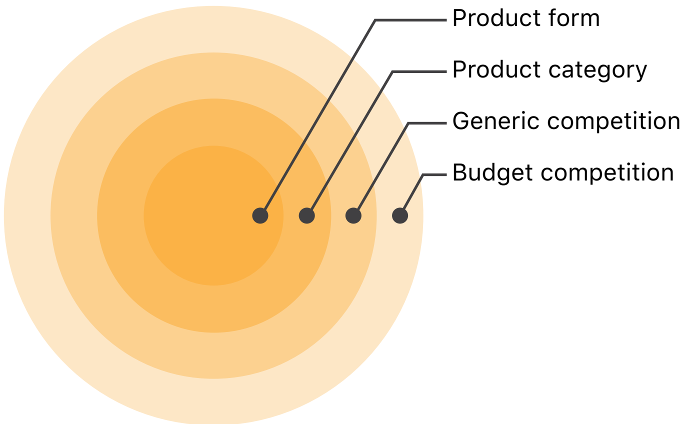


Fig. 2.26: Lehmann & Winer's levels of competition model

AR menu competition

The product form competition is when other companies are also creating augmented reality menus for restaurants. These are the biggest competitors, as the possibility to differentiate from them on major USP's is very minimal. Leaving often only the option to differentiate on geography, business model, features, or vision. While there are a handful of AR menu competitors out there, only two of them are relevant based on their progress and location. These are Kabaq and FoodStory.

Kabaq

Kabaq was the first company ever to create an AR restaurant menu, started at the end of 2016. Their main target market is the United States, as they operate from New York City. Briefly after their launch they had already been acquired by The Glimpse Group in December 2016, allowing Kabaq to utilize the network and knowledge of this VR and AR holding company.

While already in development for 2 years, Kabaq seems to still be looking for product market fit. Next to restaurant menus they are active in many other markets such as catering, marketing campaigns and Snapchat filters. Based on their social media and press coverage they seem to be mostly active on collaborating with big nationwide brands on marketing campaigns using their 3D food models.

Since Kabaq is only active in the US, they are not a dangerous competitor at the moment, since the focus is on a different geographical markets. However, if they decide to focus on the Dutch or European market they likely become the #1 competitor right away.

FoodStory

FoodStory is a Dutch startup that developed an AR menu as a part of their existing AR startup Arbi. Their idea is that consumers will install their FoodStory app on their own phones, and with this app they will be able to browse the full menu in Augmented Reality.

FoodStory can be considered the biggest competitor due to their location in Amsterdam and a very similar product. They only started in the beginning of 2018, and after an initial demo launch in March seem to not have made any updates to their app or website as of November 2018. While maybe operating under the radar until a big launch, it is also possible they might have put this project on-hold due to lack of success. Initial prices on their website (now removed) suggested a €99/month fee and a one-time fee of €75 per dish for the scanning. Especially the one-time upfront fee can become very high when scanning a full menu, this could have been a cause for lack off success. As based on insights from interviewing restaurant owners, they are sceptical of trying new and unproven products that come with high upfront costs.

Their price is still reasonable for this service, as taking the photographs and recreating the model takes a lot of manual labour. Therefore it might be a good decision to aim for developing an automated scanner, as this will form a USP over FoodStory and can allow for low upfront costs.

Their decision to focus on consumers installing the app on their own devices also might be a mistake. As was concluded from chapter 2.2, many consumers still have a phone that is not capable of AR and it likely will take 2-3 years before this group becomes negligeable.

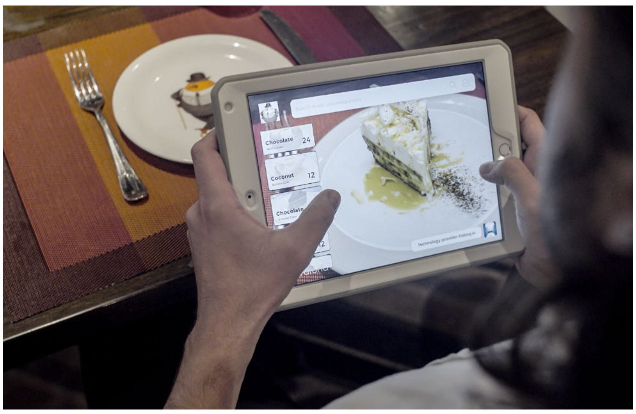


Fig. 2.27: Kabaq's AR menu used on an iPad in a restaurant

Fig. 2.28: FoodStory's AR menu demo

Other menu competition

Product category competition can be categorized as all other companies developing restaurant menus. These menus can be roughly distinguished as either nondigital physical menus, electronic in-store menus, and online menus.

Looking at all the available other menu solutions on the market over 50 companies have been analysed. Due to the sheer number of competitors on a worldwide basis, the scope of this search was mostly limited to Dutch companies offering menu solutions. Some international players who offer unique solutions not available on the Dutch market were however still included.
From all these available products, 9 product categories have been defined. Each of the categories is described briefly and the status of the competition for each is elaborated.

Printed menus nondigtal phsyical menu

Still by far the most common option for restaurants, the traditional printed menu. These come in all creative shapes and materials, but in essence they are a non-interactive list of everything the restaurant has to offer. Some restaurants decide to add pictures of the meals to make the menu more visual, but in general the majority of restaurants decides to omit these. Reasons for this might be lack of space, lack of proper photos or fear that it gives customers the wrong image of the restaurant, as photos on menus are often associated with cheap places.
Few companies actually specialize in just making restaurant menus. Many are made by big printing companies who offer printing menus as one of their many products. Thus likely little competition can be expected from these companies if restaurants are convinced of the switch to a digital menu.

Sampuru nondigtal phsyical menu

Sampuru is the name for fake food models, made out of plastic or wax, often only found in Japan. Sampuru has grown to a multi-billion yen (1 Euro = 130 Yen) industry in Japan alone (Wong, 2016). Sampuru already has been around for 90 years, even before the traditional menu itself were common in Japan (Wong, 2016), but the industry never caught on in Europe. Therefore it is unlikely Sampuru companies will be competitors unless Japan were to be chosen as the target market.

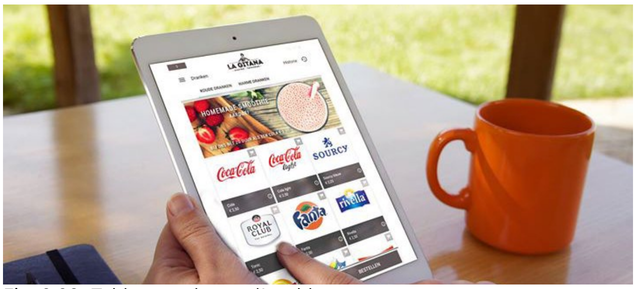


Fig. 2.29: Tabletmenukaart.nl's tablet menu

Tabletop tablets electronic in-store menu

The category of tabletop tablets can be separated into two slightly different approaches: 1) generic tablets (e.g. iPad) and 2) custom made hardware specifically for restaurants, often with an integrated payment terminal.
Within The Netherlands there are not any very big players in this product category, the biggest being Tabletmenukaart.nl. Tabletmenukaart claims to have 135 locations (MissPublicity, 2018), so this would put them at 1% market share of the Dutch restaurant market. They have been active since 2012, so their growth has not been extremely fast.
By searching restaurant review sites iens.nl and eet.nu for the word 'tablet' two trends can be recognized. 1) Tablet menus are predominantly used by all-you-can-eat restaurants, 2) Sushi places in particular often have tablet menus. They are marketed towards restaurants

as a way to increase restaurant efficiency, and increase customer spending, with Tabletmenukaart claiming their customers achieve a 10% increase in spending and could work 25% more efficient (Tabletmenukaart, 2018). Next to Tabletmenukaart.nl there are a handful of other companies offering tablet menus in The Netherlands. Most of them lack evidence of any success, with outdated websites and no recent media coverage.

Fig. 2.30: PrestoPrime EMV, a tabletop tablet developed by Presto (US)

The second category, of custom made hardware for usage as a tabletop tablet, is mainly a big trend in the US. Where companies like Ziosk and Presto are currently very big players with over 250.000 active tablets combined. This success is likely due to the US restaurant industry being extremely focussed on efficiency, something these tabletop tablets can provide.

In The Netherlands these devices have not been introduced yet. There is only one company, Vision Menu, who develops their own restaurant tabletop tablet. While they raised €125k in crowdfunding (Collin Crowdfund, 2016), there is no evidence yet that they are successful.

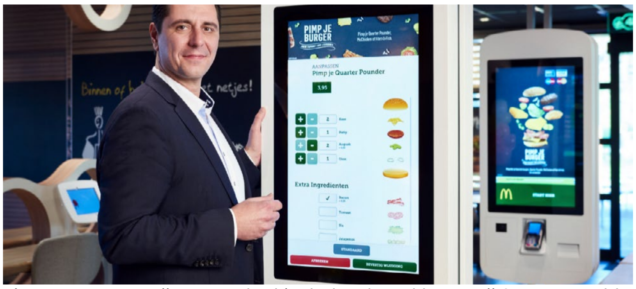


Fig. 2.31: MC Monji easy order kiosk developed by Monji for McDonalds

Self order kiosks
electronic in-store menu

Rapidly increasing in popularity the last few years are self-order kiosks. These kiosks allow customers to browse the menu, decide what they want to order, and pay, without the need for staff members to assist.

They are mainly used by high throughput restaurants in order to serve more customers and save costs on staff.


Fig. 2.32: Flatmedia's narrowcasting menu solution

Narrowcasting
electronic in-store menu

Narrowcasting can be defined as simply displaying information on displays. In restaurants these are used as permanent displays of the menu, often hung above the counter in take away restaurants. They provide the possibility to quickly and more often change the menu, often with little to no extra cost to do so.

Similar to printed menus, narrowcasting just for menus is not something companies specialize in. Narrowcasting companies have clients from a wide variety of sectors, and thus likely would not react if their market share in the horeca sector starts declining due to restaurants opting for other solutions.


Fig. 2.33: HoloLamp projecting a 3D food model as a hologram

Holographic menus
electronic in-store menu

Portable holographic projectors are a new upcoming technology, with the French startup HoloLamp being the most promising one. The Dutch company Holofil also claims to sell a holographic display, but their technology based on Pepper's ghost (Holofil, 2018) shows a 2D image with no actual depth.

While exploring multiple markets, restaurants seem to be their initial target market as they specifically have a webpage and demo videos for a dining usage scenario.

While this technology is a great solution for hands-free and glasses-free AR, it likely will take a few years before it would be commercially available at a price restaurants could afford, therefore making these companies not an imminent threat, but only a potential future threat.

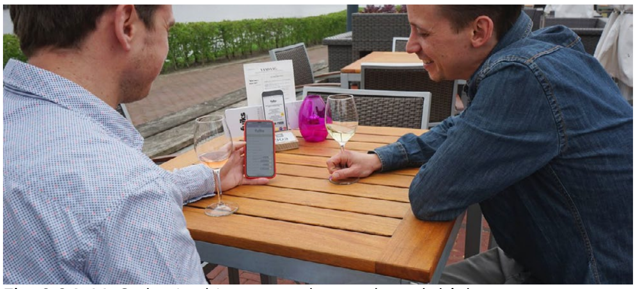


Fig. 2.34: MyOrder (web)app to order meals and drinks at a restaurant

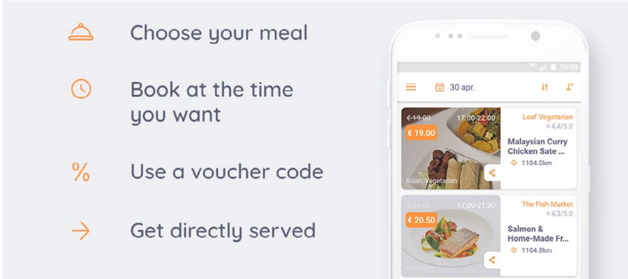


Fig. 2.35: MenuBlender

Mobile ordering apps

online menu

Ordering apps where consumers order with their own devices at restaurants have been tried before, but failed. This was in 2010 when MyOrder launched their app for mobile ordering for a variety of use cases, one of them being restaurants. After trying many markets over the years the company opted to pivot to a mobile app to pay for gas and parking, which they are developing nowadays. A reason for their failure in the restaurant market (and many other markets) likely lies within their timing. In 2010 many consumers did not even own a smartphone, and concepts like mobile ordering and paying were completely unimaginable for them. Therefore being too early in a market is a mistake that can kill startups if they do not have the resources to wait for consumer behaviour to catch up.

Now in 2018, startups are trying this concept again, with apps like MynOber (see figure 2.34) and Jamezz creating ordering apps just for restaurants. While active for less than a year, their solutions seem to be promising as MynOber stated to have once gained 8 new clients in a single week (MynOber, 2018).

These apps are in line with results from restaurant interviews (see chapter 3.3), where restaurants stated interest in ordering apps as a solution for their high staff costs. Their motivation for this made it highly interesting to add ordering capabilities to SeeFood or even pivot to an ordering app. Resulting in ordering app startups perhaps becoming just a big of a competitor as other AR menus.

While these existing apps will have a first mover advantage of about a year, they can still be considered in early development. Leaving enough opportunity to capture a part of the market share before the ordering app market would consolidate to a few companies.

Pre-ordering apps

online menu

While seemingly very similar to the previous category of ordering apps, these apps are meant to browse a restaurant's menu and place your order in advance. So that when you arrive at the restaurant your order has already been made. This is meant for consumers who want or need to save time on their restaurant visits. Therefore likely limiting their potential market to busy people and take-away restaurants.

Rotterdam-based startup MenuBlender (see figure 2.35) is one of the companies developing such an app. Their target market is business lunches, where the time available to spend at the restaurant is often very limited. With 30 launching customers just in Rotterdam their app seems like a success on the restaurant side. However, with no usage in-restaurant, MenuBlender is responsible for end-customer acquisition convincing people to order their lunches up front. In this scenario, customer usage, rather than amount of restaurants signed up, will ultimately determine the success of these pre-ordering apps. As of now, this market is still too new to determine whether it is successful. If it turns out to be, 3D food models would be a good fit for this market, making it a possible future direction or interesting for partnerships.

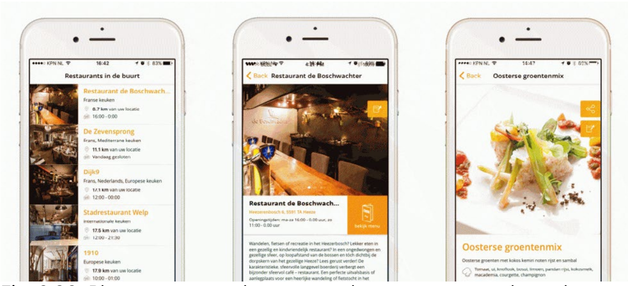


Fig. 2.36: Photo menu app, browse nearby restaurants and see the menu

Orientation menus

online menu

Lastly, the category of orientation menus consists of websites and apps solely for informing people about what restaurants have on the menu. These are often part of the restaurant's own website, and part of the product a website developer delivers to restaurants.
With SeeFood also envisioned for customers to use for restaurant orientation at home, other orientation menus are still considered a product category competitor, rather than a generic competitor.
Few companies focus solely on providing just orientational menus, photo menu (see figure 2.36) being the only one in The Netherlands. The market for such apps seems to be small, as consumers likely are satisfied with a restaurant's website listing the menu.
It is possible to see SeeFood's 3D models when visiting a website, therefore proving a market opportunity to also add these models to the restaurant's website as an extra service. Rather than competing with restaurant website developers, it would be easier to form partnerships with them to realize this.

Generic & Budget competition

The last two types of competition are generic competition and budget competition. As these are both indirect competitors the amount of competition to be expected is quite low. Therefore, these competitors are discussed in little detail.

Fig. 2.37: The devices included in Gastrofix's POS system

GENERIC COMPETITORS

The generic competition consists of other digital services aimed at restaurants. Most important competitors in this space are POS systems. These systems handle all the payments within the restaurant, but often also provide features to keep track of what each table has ordered, automatically send order to the kitchen, and provide a range of integrations with other systems. Due to this integration possibilities many POS system providers already have partnerships with tablet menu providers and mobile ordering apps. And some of these providers might choose to develop their own menu solutions in the future, becoming direct competitors.
Other competitors on this level would be restaurant review sites (Iens.nl, Eet.nu, Tripadvisor), deal sites (Groupon, SocialDeal), reservation systems, kitchen management software, employee roster planning software, and many more.

BUDGET COMPETITORS

Lastly, budget competitors describe all other products the customer can decide to spend their money (budget) on. For SeeFood the customers are restaurants, they might decide to spend their money on for example marketing, hiring more staff, buying new kitchen appliances or redecorating the restaurant.
More interesting would it be to take a look at restaurant visitors, so what the budget competition of a restaurant would be. This might be regular supermarket shopping, food boxes (e.g. Hello Fresh), vending machines, or (one very interesting competitor category in this space) home delivery.

Fig. 2.38: Deliveroo driver delivering an order

Home Delivery

While this market might seem very similar to ordering and pre-ordering apps, the reason it belongs in budget competition is the fact that these services aim to bring the food to your home, rather than you visiting the restaurant. Just for some restaurants these apps are considered a competitor. As for others they provide extra opportunities for selling meals.
Consumers increasingly opting for home-delivery over restaurant visits is likely to change how restaurants operate, resulting in more ghost restaurants (see chapter 2.4 trend #4). However, for such a change to have a meaningful impact in terms of competition for SeeFood, this would likely take years and a strong shift in consumer behaviour. If the market does shift it would be important for SeeFood to recognize this and potentially pivot to being a provider of 3D food scans for the home delivery market, making it important to keep track of this shift.

In conclusion

Having analysed the total competition, a few important learnings can be made.

AR menu competitors seem to fail gaining market traction in the restaurant space, or decided to pivot into alternative markets. While this is difficult to definitively conclude as there are only a few AR menu startups, and this has been concluded based on their behaviour. Blatantly copying what these competitors are doing would therefore be risky, as it could lead to the same mistakes that are likely causing them to be less successful than expected at restaurants. A co-creation approach in collaboration with restaurants could prevent such making mistakes during development, or lead to a conclusion that AR menus are not a feasible solution for restaurants at this moment.

Tabletop tablet menus are very popular and successful in the US, but fail to gain significant market share in the Dutch/European market. One possible explanation might be the restaurant dynamics in the US being focused extremely on quick customer rotation, which such tablets can provide. But as was concluded from the trend analysis, the increasing staff shortages in the restaurant sector and more technology usage could lead tablet menus becoming more popular here.

Online menus for mobile ordering are perhaps the most promising new contender for digital menu solutions. While having been tried before and failed, a new wave of startups in 2018 is now again trying to build this. These menus provide the cheapest possible solution for the biggest problem in the restaurant sector right now: expensive employees.

"The trick is, a market has to be nonexistent when you start. If the market is large early on, you will have too many competitors. You have to make it large."

- Douglas Leone, venture capitalist

03

VALIDATE

In this chapter

In this chapter the core idea of SeeFood, an augmented reality menu for restaurant, is tested using market validation. A series of interviews with people in the target market were conducted to determine whether the concept has potential in the market. While discovering all the problems that are prevalent in the target market, the aim is to reach a problem-solution fit. This is the point where the concept of SeeFood would make sense to develop since it solves enough major problems for the target market.

3.1 Customers & Users

Because SeeFood is a B2B2C proposition, the customer and the user are two different persons. The target market of customers and users is initially very broadly defined as all restaurants and all users. This scope became narrower throughout the project due to new insights from validation and desk research.

The customer is the restaurant. For smaller restaurant this would likely be the restaurant owner or owners, while for bigger restaurant chains the customer is likely a procurement person. Their intention to buy SeeFood would likely be a very rational decision based it on what it would add to their restaurant and what problems it solves.

The users can be defined as the restaurant visitors, as well as the restaurant personnel. However, when mentioning the 'user' in this report it refers to a restaurant visitor, unless stated otherwise. The visitors will be the core users of the product, interacting with the product throughout their visit. The personnel on the other hand will interact with SeeFood when updating the menu, when introducing the menu to visitors, and when preparing and serving orders (when the in-app ordering feature is available).

Assumptions

Prior to speaking to any customers or users, everything what I presume that they want, like, and think are all still assumptions. The importance of validation is to significantly lower the uncertainty of these assumptions, by discovering that a majority of people either validates or rejects these assumptions. Since the customers and users have very different interests for the product, two separate lists of assumptions were generated. These lists can be seen on the next page.

Next to all these assumptions there are a lot more assumptions about both target groups. Some were irrelevant, others could not be researched during the validation phase, yet others were unconscious assumptions which only became prevalent after someone rejected the assumption.

Customer assumptions

- **Primary interest is more revenue**

Decision making by restaurant owners is assumed to be driven by revenue, rather than idealistic or personal reasons.

- **Printing paper menus can be expensive**

Restaurants need to reprint the menus when they change the menu or when they are torn or dirty. It is assumed that this is considered expensive for some restaurants.

- **Perceives the inability to make quick changes to a (paper) menu as a drawback**

Current menus do not allow for easy changes to the menu as they would require reprinting, it is assumed that restaurant see this limitation as a drawback of their current menu.

- **Likes to make changes to the menu more often**

As a potential result of the point above, restaurant would like to change the menu more often if they had the chance to do so.

- **Would not mind cutting staff to have greater efficiency**

A major benefit of a digital menu would be the possibility to work more efficiently, it is assumed that restaurants are willing to cut down on staff so that they can save costs.

- **Is open to using technology at the dining table**

Restaurant owners are assumed to be open to more technology usage in the restaurant in general, as this could give their visitors new and better experiences, and it could save costs.

- **Need to differentiate from competition**

With the amount of restaurants there are growing quicker than the market is growing restaurants are assumed to want ways to differentiate themselves from competitors.

- **Is worried of tablets getting stolen or broken**

When using tablets as digital menus restaurant owners might be worry about them getting stolen or broken. If that is the case, the theft- and hufterproof aspects need to be defined and communicated clearly.

- **Want a 3D scanner that is always available**

It is expected restaurants like the scanner to always be available, so that they can update the menu immediately when new meals are added, can have 3D models of a daily dish, or to create new temporary 3D models when an ingredient is out of stock.

User assumptions

- **Rather want to see the food before ordering than be surprised by it**

It is assumed guests like to see what they are going to get. This was one of the reasons this project started, but this assumptions needs to be validated if it holds true for a majority of people.

- **Prefer 3D models of food over images or text**

If the first assumption turns out true, it can then be assumed that people would prefer virtual 3D models as a way to see the food, rather than seeing images or reading descriptions of it.

- **Want to have a personalized experience**

People might experience interacting with a digital menu rather than with staff members as an impersonal experience. It is assumed people still want this personal experience at a restaurant, therefore creating a requirement for the digital menu to have personalization options.

- **Generally like interacting with restaurant staff**

It is assumed people like interacting with restaurant staff and that they do not want to lose this interaction.

- **Is open to using technology at the dining table**

Similar to whether restaurant owners are accepting of technology usage at the restaurant, this same thing can be assumed of visitors. The previously noticed trend of digital wellbeing (see chapter 2.4) could perhaps also have a big impact on how people like to see technology usage in restaurants.

- **Perceive SeeFood as a differentiating factor**

If the assumption that restaurants need to differentiate from their competition holds true, it should also be assumed that visitors do see having SeeFood as a differentiating factor.

3.2 Talking to Users

During the first months of the project a small study was conducted consisting of small interviews with potential users. The main goal of this study was to determine whether SeeFood provides a solution for problems people experience during their restaurant visit. Another purpose was to discover other restaurant related problems, these could provide options for future features or potential pivots. Lastly, the study also aimed to define a target audience of what type of restaurant visitor would want this and what people value when visiting a restaurant.

Method

Almost everybody visits restaurants, so anyone was fit for this study. Although people with prior knowledge about the project were not considered, due to the approach that was used. The approach was to ask three consecutive questions to everyone:

1. What problems do you experience when visiting a restaurant?
2. Specifically for the menu, what problems do you experience with the menu (if any)?
3. *After explaining the concept of SeeFood* What do you think about this?

The intention was to not give away the context of the project during the first question, this was to discover if menu related problems would be among the most important problems people experienced at restaurants.
The second question aims to uncover all problems people perceive with the menu, still without them knowing what the project is about to prevent a bias towards answers that the concept solves.
Lastly, the concept is explaining to them, making sure they understand what it is about. Asking them their opinion about it.

Results

Interviews were often conducted during social events: Venture Café Rotterdam, various fairs, parties, while talking to store employees, etcetera. Because of this situation only some insights were documented into short notes after the interview or after the whole event, others were recalled from memory when drawing conclusions. Therefore, these results have very little academic significance, but from a startup perspective still provide adequate validation.

Analyzing the insights from the interviews, four groups were recognized from the participants. Where each group had their own unique problems with the menu and a similar opinion on the SeeFood concept. They can be classified as: (Participants can be in no group or in multiple groups)

- Diet minded (e.g. vegetarian, vegan, allergies)
- Picky eaters
- Internationals
- Older generations (age 38+, not millennials)

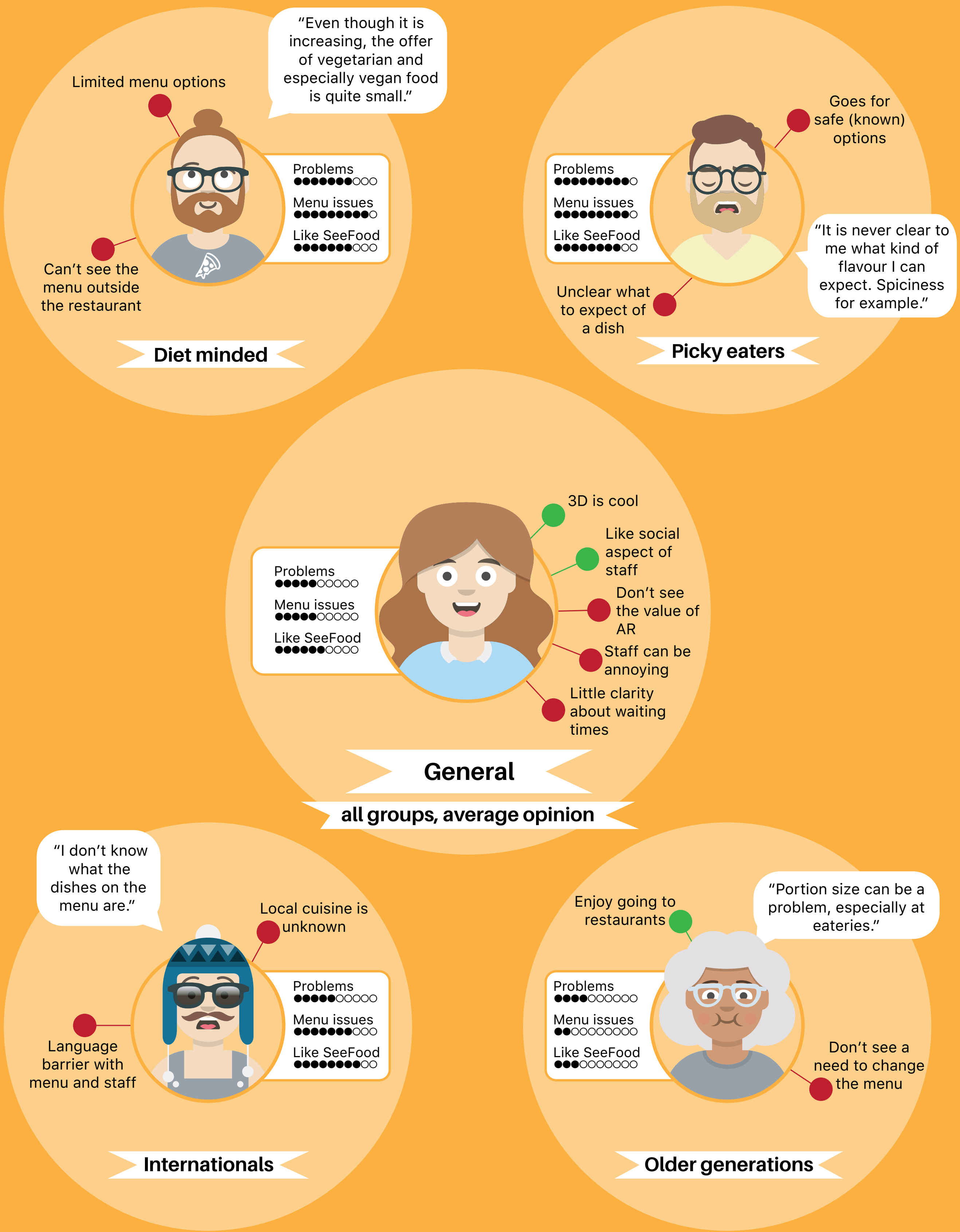
Interview Setup

24 interviews
9 men / 15 women
6 international / 18 Dutch

Venture Café
Fairs
Parties

5 – 30 minutes
3 main questions

Interview Results



Both diet minded people and picky eaters are characterized by their problems of little choice at a restaurant. For diet minded people this is because they cannot or do not want to eat part of the menu, often not knowing how many options they have before entering the restaurant and unaware of dishes that can be altered to their diets. For picky eaters however, the little choice is created by their hesitance to trying new foods, where they only choose from dishes they know they would like. Both these groups experience many problems with current restaurant menus, surprisingly these groups also experienced the most non-menu related problems at restaurants. Especially some picky eaters seemed to have problems with nearly everything in the restaurant.
The concept of SeeFood resonated well with these groups, likely because part of their problems could be solved with such a solution.

Internationals are often problematized by their lack of the Dutch language and culture. Causing problems when reading the menu, either it being completely in Dutch or they are unknown with what some of the dishes are. However, apart from the menu they had relatively little other problems at the restaurant. They liked SeeFood especially as a solution for their language problems with the menu.

The older generations perceive the least problems at restaurants or with their menu. Going in depth in some interviews this group actually experienced many of the same problems picky eaters had, the difference being that this group did not really experience these occurrences as major problems. An explanation might be that they have become inured to some problems at a restaurant.
Their opinion on SeeFood was characterized by a lack of need for change. While not disliking it, they did not see any added value it could provide for them.

In general everybody experienced some sort of problems at a restaurant. Most also experienced some problems with the menu, however these problems were only mentioned after the second question asking them specifically for menu-related problems. Exceptions to this were people in groups who experienced the most problems with the menu: diet minded people, picky eaters and internationals. They often mentioned some menu-related issues as one of their main problems at a restaurant.
A major problem for everyone seemed to be staff. This was for a variety of reasons, ranging from unfriendliness, lack of knowledge, being forgotten, asking for orders at the wrong moment, to communication problems. Paradoxically, the people who experienced problems with staff were also the people that mentioned they liked the social interaction with staff and did not want a digital menu that would completely get rid of the staff.
Specifically on the concept of SeeFood there was one major opinion: “3D models are cool, but I do not see why augmented reality is necessary.” They liked the idea of 3D models of their food, but still had questions about how realistic it could be, given that they were not shown any 3D food models during the interview. They also feared that the 3D models might be misleading, often referring to experiences with images of food that look a lot better than the actual meal. For example, a supermarket frozen pizza with a box that displays a perfect pizza with plenty of toppings rarely resembles this picture in reality.
The addition of augmented reality to all this was often not understood. People did not see a need for augmented reality in this context and were mostly questioning why you would add this. The possibility of being able to get an idea of the actual size of a meal because of AR was a valid argument for them, but did not convince them that AR was necessary. A potential hypothesis for this is that they denigrate augmented reality because of prior experiences. As became apparent from the exploration chapter, the introduction of ARKit and ARCore in late 2017 are considered a massive leap forward in AR quality. Many people likely had not yet seen such an AR app in early 2018. Since the participants of this study were not shown any augmented reality experience that can be provided with these new technologies, this hypothesis is something that should be investigated further in a pilot where people are shown a prototype of the SeeFood augmented reality menu.

Arguments against SeeFood

Although few people were opposed to the idea of SeeFood, some mentioned reasons why they would not want to use it. There were three reasons which were mentioned multiple times:

'It ruins the social experience'

People go to restaurants for a social experience together, many view smartphone usage at the table already as something that ruins the dining experience, and some fear that a tablet device on the table at all times would even worsen this. But, this might be a misconception. Because of high tablet prices restaurants would likely utilize a tablet that can be used by up to 4 people, as already is being done by tablet menu competitors. This shared usage of a tablet menu, which is very inviting for exploration due to the novelty for most people, would likely increase social interactions and discussions about the menu compared to when using a traditional paper menu.

'I want personal contact with the staff'

As mentioned earlier, people like social interactions with restaurant staff. Even though they also experience many problems with the staff. An explanation for this paradox might be that the need for social interaction at a restaurant is a fallacy. Pieter Levels explains this for a similar situation with hotel staff as: "People confuse a business process for a human interaction, merely because it was always like that" (Levels, 2018). The social interaction with restaurant staff mainly serves a business purpose, and removing this could potentially increase social interaction with friends. While some people would disagree with this opinion, restaurant staff automation is likely to happen in the future due to the enormous cost savings this automation could bring. Making it boils down to an economic question in the end: Are people willing pay more money so that they can have a social interaction? Making human interaction possibly a luxury product in the future.

'I like to be surprised'

Some people mentioned that they like to be surprised in a restaurant, and thus like the ambiguity a traditional menu offers. They fear that this surprise element would be lost when using SeeFood and seeing 3D models of their food. This is partially true; the visual surprise element of a dish would be lost when viewing a 3D model of the dish. But the taste and smell of a dish cannot be easily conveyed through a screen, leaving still some surprise left. For people that still dislike missing the visual surprise, an easy solution would be to give them an option to hide the 3D models (or merely their texture) when they use the app. However, walking into a restaurant and seeing the menu and the 3D models for the first time will also give you the surprising effect.

In conclusion

It seems that many consumers are unaware of what is possible with augmented reality, and indicate that they do not want it without having experienced it. To see whether that is actually true, a later test needs to be conducted showing users an actual augmented reality menu.

As staff is a major cost for restaurants it would be interesting if people would be accepting of staff automation. While many people mentioned problems when interacting with staff, paradoxically, those same people also mentioned they liked the social interaction with staff and they would rather not see them replaced. This makes for an interesting contradiction, as not wanting a digital menu in order to maintain interactions with staff might be a fallacy. This fallacy is discussed in more detail in the previous subchapter 'Arguments against SeeFood'.

The people who benefit the most from a menu solution like SeeFood are people that do not like or do not want to eat certain meals. They experienced the most problems with the menu
Older generations especially were less interested in SeeFood, and saw little need to change the menu. This is in line with earlier insights from the exploration phase that centennials and millennials would be the best type of target audience for using such a product.

Also reflecting back on the initial assumptions about the users, some of these assumptions can be validated or rejected:

- **Rather want to see the food before ordering than be surprised by it**

Inconclusive – While many people expressed interested in seeing their food upfront and did not care as about being surprised, there still is a group of people with a preference for being surprised. But as explained in the previous paragraph, this is not an issue.

- **Prefer 3D models of food over images or text**

Inconclusive – This assumption turned out the be difficult to validate without a controlled experiment showing users all three options. It is still a relevant assumption that needs to be validated later on.

- **Want to have a personalized experience**

Inconclusive – The want for a personalized experience at the restaurant was only brought up a few times by some participants, suggesting it might not be of a great interest for most people. This cannot be assumed solely from a lack of responses on this topic, since the participants were not asked specifically on their opinion about this topic.

- **Generally like interacting with restaurant staff**

Validated – Even though people mentioned problems they experienced with staff, these same people also said they like the human interaction with the staff. This assumption however turned out to be wrongly formulated for the goal it tried to achieve. As it presumed when people like interacting with restaurant staff that they would also dislike losing this interaction due to staff automation. This latter assumption however might not be true for everyone, as can be read in the previous subchapter 'Arguments against SeeFood'.

- **Is open to using technology at the dining table**

Inconclusive – Opinions on this assumption are mixed, some people have a dislike for technology at the dining table due to the belief that it would ruin the social experience.

- **Perceive SeeFood as a differentiating factor**

Inconclusive – People did not mention it as a differentiating factor by themselves, and in retrospect this assumption could be better validated using some AB testing where the presence of SeeFood is the only differentiating factor between two versions.

“People don’t know what they want, until you show it to them.”

- Steve Jobs, founder Apple

3.3 Talking to Restaurants

To develop empathy for restaurant owners it is necessary to get to know their ins and outs. Get to learn their business and what problems they are facing. To achieve this, a few long qualitative interviews have been conducted with restaurant owners. These interviews will give some validation whether restaurants would be interested in the proposition of SeeFood, and discover what would be their biggest needs and their doubts.

Method

A few prerequisites for the type of restaurant that would be interesting for this research have been determined. These criteria were determined to weed out restaurants that would likely not be interested in purchasing SeeFood. In the future it might be interesting to specifically reach out to those restaurants to validate whether this assumption that they would not be interested in SeeFood is true.

- **Restaurants should have a menu, with more than 5 food items.**

Restaurants that do not have a menu often serve a different meal each day, or those with a short menu have items people are familiar with and will know what to expect. When there is no to little choice there would be less to gain for a restaurant from a concept like SeeFood.

- **Restaurants should mainly be menu focused: not be the ‘surprise 5-courses dinner’ type of restaurants.**

At these restaurants the table d’hôte menu is often the most popular options, with few people deciding to choose à la carte (if available at all). Presumably there is a bigger profit margin on these predefined multi-course meals, due to economies of scale in wholesale ingredients and more efficiency in preparation. So with both the visitor and the owner preferring table d’hôte, there is likely little need for a menu that might make the visitor doubt.

- **Restaurants should have somewhat visually appealing meals.**

If restaurants only serve mainly dull looking meals, like soup or stew, the visual aspect of seeing the meal would not be of interest to visitors (except for getting an idea of the meal size). Seeing the meals before entering the restaurant in this case might even scare off some visitors.

- **Restaurant is located in Delft (or nearby).**

This selection criteria was to make it easier to visit the restaurants for the interviews. Whilst also making sure that if restaurants would be interesting in becoming a customer in the future they would be close-by. So if SeeFood were to become an actual startup many on-site assistance would be needed in the beginning, restaurants close by would allow for a quicker response time.

A list of over 50 restaurants was made, and if they fitted these prerequisites the restaurants from this list were approached with the question if they wanted to participate in a MSc research interview. The full list of restaurants can be found in Appendix A.

Interview Setup

6 interviews

At their restaurant

45 – 90 minutes
7 topics

The few restaurants throughout The Netherlands that were already using tablet menus were also considered and approached. Unfortunately, none of these restaurants or chains responded to email requests for interviews. Later opting to cut these restaurants out of the scope, and approach them again at a later stage.

In general, restaurants were not very responsive to cold emails (<10% responses), the data from the elaborate restaurants interviews were further validated with some questions during Letter of Intent testing. See chapter 5.2 for more on the Letter of Intent method.

The interview consists of a questionnaire to get to know the ins & outs of the restaurant. In this questionnaire 7 topics are discussed: their restaurant, the problems they encounter, their menu, innovation, their digital systems, their finances, and their opinion SeeFood. For the complete questionnaire please see Appendix B.

Results

The findings of the interviews have been categorized according to the discussed topics. Results varied heavily and seemed conflicting at times.

Problems

Asking restaurant owners what their main problems were, a few answers came up multiple times. The most pressing issue seems to be around hiring staff, which was already clear from news articles but now also validated by restaurants. It is difficult right now to find the right personnel, in particular especially finding cooks was an issue.
Other staff related issues were around scheduling. The restaurant sector can be very weather dependant, and it is difficult both for restaurant owners as well as staff members to ensure there is always exactly enough staff scheduled. This also lead to difficulties for some restaurants of keeping personnel happy, as the amount of hours they can work in a month is always uncertain.

Complaints from visitors are most often about human errors: waiting extremely long for the food, order forgotten, or drinks being delivered at the wrong table. This reflects a recurring problem busy restaurants often face:

"In the evening the biggest problem is always serving the correct meals and serving them on time. Usually we have it under control, but it is always a challenge"

While often preferred by visitors, paying separately is a big annoyance for restaurants:

"After lunch I'm spending half an hour on paying, as everybody wants to pin separately"

This way of paying often gives the problem that there are items left on the tab after everyone has paid, taking even more time before the full tab is paid. While often leaving hardly any tip as no one feels individually inclined to do so.

Menu

Asking restaurants how their menus came to be a few things were interesting to note.

Pricing wise, no owners actually had any real strategy behind this. Most often restaurant take a look at their competitors and decide to go for similar pricing, while others would look at the pricing for all the ingredients and add a set percentage margin to each of those.
Every restaurant makes their biggest margins on their best sellers. Some owners did this intentionally, knowing which products sell well and adding extra margin to those, as people would still buy them even at a higher price. For example bitterballen can have a profit margin of 500%.
Other restaurants decide they do not want to put extra margins on their best selling products. But even unintentionally these restaurants will make a bigger margin on their best sellers, as these products bring volume advantages when buying wholesale ingredients.

Regarding the law passed in 2014 that requires restaurants to provide information on allergies (Stichting Horeca Onderwijs, 2014), few restaurant owners seem to care about integrating this into the menu. While most indicated they wanted to add it to the menu, it was

not something that was very important for them to do anytime soon. One owners added them just to get rid of the questions about it:
"I did put those icons on the menu, as the questions about it were driving me crazy"
Changing the menu is not something restaurants do very often. Most like working with a seasonal menu that changes every 3 months, next to a main menu that is available year-round. However, daily or weekly dishes are quite common.

Innovation

Some owners have ideas about innovative solutions and using technology in their restaurant, but they lack the technical skills to do it themselves and the idea ends up being unused.

"I actually wanted to work with tablets 5 or 6 years ago in my lunchroom"

Asking why they never ended up doing that:

"We do not have that knowledge, I have good ideas but then I have to know people who are going to build that. Yeah, we had ideas about apps 15 years ago, 10 years ago. Those do exist now, but we could have done that. But no idea how, and we also do not have the people around us that say who or where to go to with the idea."

But while these owners were very open towards new technologies, others are more hesitant towards new technologies and change in general. Immediately getting into defensive statements why some ideas would not work for them.

"Q: Have you ever been approached by Deliveroo or similar companies?
A: Yes by Deliveroo, but that is not something for us.
Q: Why not?
A: I do not think people are waiting on that. You cannot expect a steak that has been cooked to still taste correctly after it has been warming container for 15 minutes"
Q: But have you actually tried whether that's true? As Deliveroo likely would not approach you if they did not think people would buy your meals.
A: No we have not tried it."

Especially these home delivery platforms becoming a bigger topic for restaurant owners. Deliveroo seems to be the most aggressive in approaching many restaurants. Pricing wise Deliveroo's service is also most loved by restaurant owners, as the cut they take is a lot smaller than for example Thuisbezorgd, allowing restaurants to still make a small profit on meals sold through Deliveroo. Doing delivery by yourself is not something restaurants could feasibly do, as promoting it to get customers is especially difficult. Big players like Deliveroo or Thuisbezorgd take care of all the marketing efforts, as well as complaint handling. Making collaborating with such a partner often the only feasible option when a restaurant wants to do home delivery.

"Deliveroo is very reasonable, they actually only charge our personnel costs of driving back and forth"

About other innovative solutions for the restaurant industry, owners are less happy. Restaurant review sites like iens can especially be harmful to a business:

"iens determines the market at this moment, if small restaurants do not participate in iens, then they just go bankrupt"

Also the likelihood that people will leave a review is much higher when people have had a negative experience, resulting in review websites not reflecting how people actually rate the restaurant.

"People have eaten well, loved it, the last thing you say when they're leaving 'leave a review on Facebook if you want to'. 'Yes will do'. But, they do not. But if it was bad, then there might be something to get. 'We may be able to claim a free burger, let's start complaining' "

Next to review sites, coupon and deal sites were also not very popular among restaurants who tried them.

"You get bargain hunters. You get people who want the best, for the lowest price, want the most, and on top of that complain and never come back because they will be going to the next deal."

Restaurant owners would like to do something against these big companies controlling the market. But they feel that there is nothing they can do.

“Ideally, we all say ‘yes, lets stop with all those company’. But 1000 say it, and only 2 do it. And then there you are. It is very difficult to challenge these big companies.”

But even with many negative experiences of innovative solutions for the restaurant industry, most owners said they liked being approached by innovative parties about new products.

“Speaking to an expert about something I have little knowledge of. That is nice.”

To stay up-to-date on the latest innovations, almost all owners visit trade fairs. But rather than an inspirational event, most go there with a specific interest in purchasing something and comparing offers. Some also read the trade magazines.

Digital systems

In terms of digital systems within the restaurant all restaurants nowadays have a POS system. Some are really happy with their provider, while others are unsatisfied with the lack of options or versatility their system had. However, they do not decide to switch to a competitor, even though they are not bound by a contract to stay with their current provider.

They all would prefer one system that combines everything. Which none of the big players seem to offer.

“Reservations, etc., they are all external companies. I would prefer one package, in which reservations can be made, that puts it directly into the POS system. That you only have one back office. Now I am working with 3-4 things.”

Finances

Staff is often the biggest expense for restaurants, at an average 27% of a restaurant’s revenue for the whole Netherlands (Heitkamp, 2015). With a tight labour market currently in The Netherlands more than 1 in 5 restaurants is hindered by a lack of staff (CBS, 2018). Due to this the cost of staff is likely to make up even a bigger percentage of the total revenue, with some restaurant owners mentioning up to 50% of their revenue being spent on staff. Restaurant owners expressed they were willing to automate staff to reduce costs, the only exception being high-end restaurants who highly value the personal aspect staff interacting with visitors brings.

Selling drinks is the most important for restaurants. These require very little time to prepare, so one employee can serve much more people compared to when serving food. While still making good margins on the drink prices.

“As a horeca entrepreneur you must have it from the drinks”

“Drinks are easy, costs are a lot lower. Happy to sell a lot of drinks during the weekend. Once a month a DJ evening, then you really sell a lot of drinks.”

Opinion on SeeFood

In general the restaurants owners that were spoken were enthusiastic about SeeFood, even if they saw limited applications within their own restaurant. But the restaurants that never replied to emails, or denied interview request or were not willing to even talk for a few minutes were never heard on their opinion. So likely a lot of restaurants also dislike the idea of SeeFood or digital menus in general. The reason why for this remains largely unknown, a more elaborate research going door-to-door at all restaurants is likely needed to discover this.

The opinions on how interested restaurant owners would want to apply SeeFood in their restaurant vary a lot. Some would want a tablet menu where users can order and the meals get sent directly to the kitchen. Other restaurants would much prefer having people using their own phones for such a system, as buying or leasing tablets was too expensive. And the last group only saw it as something extra; they do not want to replace their menu with a digital menu, but do want to be able to offer customers the opportunity to see the meals using their own phone in the restaurant. Especially tourists were often named for this, as they generally also prefer menus with images.

"Some of my guests would love it, others do not care."

On whether it should be tablet based or bring your own device (BYOD), restaurants overwhelmingly preferred the latter option. As they fear tablets will be too expensive, might get stolen, might get wet or dirty, and see keeping them charged as a issue. While this is understandable, it will likely still take 2-3 years before BYOD is feasible, with many consumers needing newer phones to be able to support AR. Making tablets a potential temporary solution in the meantime.

For most of the restaurant owners it seemed difficult for them to image how SeeFood would eventually work and how meals would be scanned. Most would not mind having a scanner in their restaurant permanently, but space is always an issue in the kitchen, and they likely would not have a proper place to put such a scanner. When something is not fixed in place within a kitchen, accidents are bound to happen.

While few restaurants mentioned a need for wanting to have a scanner around 24/7, they were not willing to pay a heavy premium upfront. But in order to keep the monthly price of SeeFood low, and have a little to no upfront initial costs, an automated scanner that is mainly operated by restaurant staff would be highly desirable. As this would eliminate the need for a SeeFood employee to travel to the restaurant, and also eliminate most of the manual labour of taking the photos and creating the 3D model.

For the price point restaurants all seemed to agree that paying €100-€150 for such a system (without any tablets) would be okay for them. Even if it would be just something extra for the menu and not have any capabilities for users to place their orders directly. That way, restaurants still expect that they can earn back their investment through word of mouth.

"Earning it back will be difficult. But people will talk about it. So it's also a bit of marketing of course"

Talking with restaurants who were interested in tablets, a higher price point would be okay for them. But this came with the issue that investments of a few hundred euros per month can be quite challenges for small restaurant businesses.

"It is a reasonable amount, € 400. But for us horeca entrepreneurs, it is, 10% of our rent to say. That is a serious amount. If you go to an Ikea or Van Der Valk, then € 400 is very different for them, 'oh yes, then we'll try it for a year', they do not care about € 5,000 a year. For us it is a very big risk.

We want to give you full freedom here, so you can do whatever you want. Even try messing with the POS system, that kind of stuff, you can easily start with that no problem. But € 400 each month, we cannot, we even have a window cleaner of € 100 per month and we're thinking that we can do that ourselves too"

On the subject of using digital menus for ordering, one restaurant owner did not believe that would work. He tried MyOrder back when it came up (around 2008), and it did not work for them. As it could too easily generate buildup in the kitchen, leaving customers waiting too long for their orders.

"Drinks are possible, or simple things like tosti's. But you lose the power over ordering, and I think you will get complaints then. With a regular menu, you can regulate such stuff."

Other insights

While there were many other things restaurants owners mentioned during the interviews, two of these were interesting.

Many owners seem to be busy with name recognition and publicity. Especially owners of places that struggle with getting their place full, but also for restaurants that run well this was something they were thinking about, and often seeing SeeFood fitting into this need.

Also one owner recognized the trend of restaurants completely designed to stimulate taking photos and sharing them on social media. An example of this would be The Avocado Show in Amsterdam, which became so successful that this single restaurant is now being turned into a franchise.

Fig. 3.1: Avocado burger at The Avocado Show

In conclusion

No day at the restaurant is the same. Some days restaurants might cope with understaffing and other days they might have run out of certain ingredients. Their current paper menus are static and have no way to dynamically show longer waiting times, to show dishes which are out of stock, or show variable meals (e.g. dish of the day). With an increasing amount of restaurants and other companies looking to take a cut of the market (e.g. Takeaway.com, Deliveroo, lens) margins have been declining for restaurants, making it harder and harder to survive nowadays. Staff has always been one of the biggest expenses of a restaurant, and at the moment these costs are at an all-time high due to a tight labour market. Automation would be a solution to cut on staff, which restaurant owners would happily embrace.

High-end restaurants are not interested in the complete concept, they do not want to give up personal contact with their customers. They still like the idea of 3D food models, but when unwilling to cut down on staff in the future it does not make financial sense for them to pay for SeeFood.

Restaurant owners also have their own strong beliefs on certain topics, like for example the use of digital menus. While often not very strong arguments why they would or would not want something, it seems like they party decide based on emotion and gut feeling, combined with rationale if something also makes business sense.

There are various reasons restaurants state for them to not want SeeFood:

'Too expensive, I do not want to cut on staff'

Many restaurants found it too expensive. This was mostly the response when proposing a service that included leasing or buying tablets, which would have resulted in a price of €400-€600 per month. Later, when telling about the pricing without tablet lease, which makes SeeFood cost €150 month, the price made a lot more sense and some restaurants would consider it at that price point.

'We just changed to a new menu'

A few restaurants mentioned as a reason that they do not want a new menu as they just changed to a new menu. While this reason could make perfect sense not to want SeeFood, it could also be caused by the sunk cost fallacy. If restaurants already invested money in their current menu, replacing that feels like they are throwing away their investment, but in reality switching to a new menu again might still make a better business investment. As the costs spent on the old menu cannot be recovered.

'I do not want to lose personal contact with my customers'

While this reason was especially true for high end restaurants, some other owners also stated that they would not want SeeFood or any digital menu. As they do not want to lose the personal contact with customers.
While this would be true when using such digital menus for ordering and paying, the personal contact that is takes away is the most dull and boring form of contact. If staff would not need to bother anymore with taking orders and getting the bill, they could spend that time interacting with the visitors in a more meaningful way.

'I want it later'

The most often mention reason why restaurants do not want it was that they (might) want it later. This seems to be a collection of various reasons. As they might want it later when the price might be cheaper, with a too high price being the actual reason. Or they might want it when the concept has been proven to increase revenue at multiple other restaurants. Or it could also be a polite way for them to say they are not interested. And many more possibilities.
Restaurant owners that mentioned this as a reason only have little time to tell their opinion, so there was no opportunity to keep asking 'why?'. I want it later in itself is never the reason, there would always be an underlying reason for them to not want it now but perhaps in the future. Uncovering these reasons through even more customer interviews would give a scope what to focus on to perhaps get these owners to become SeeFood customers in the future.

04

MAKE

In this chapter

Using all the learnings gained from research, it has become more clear what product should be build. For SeeFood to exist, 3D food models needed to be created. In order to greatly improve the quality and speed of capturing the photos for these models, a scanner had to be developed. Lastly, with the 3D food models available, an app for SeeFood was prototyped.

4.1 Creating 3D Models

Throughout the whole graduation project various 3D (food) models have been developed using a variety of techniques. This chapter summarizes the findings on the different techniques, software programs and other factors that play a role when creating 3D food models.

Comparing Techniques

As already explained in chapter 2.3 'Exploring 3D-Scanning' there are different techniques for 3D scanning, most used for scanning small objects (the size of meals) are white light scanning and photogrammetry. Both these methods are worth exploring, since they both come with their own advantages and disadvantages. In order to assess which method is most suitable for food items a comparison was made between the Artec Eva handheld white light scanner and photogrammetry using photos taken by the iPhone X camera.

The test subject was a hamburger from Sodexo Catering, which featured both shiny and dull surfaces, multiple colors and small details (sesame seeds). This burger was put on a white uniform cardboard plate placed on top of a rotating chair. Scanning with the Artec Eva was done with the help of Bertus Naagen at the TU Delft 3D body scanning lab (see figure 4.1). A total of 4 scans were made, the best scan was used for this comparison.

Findings

The results of the scanning are summarised in figure 4.2. The Artec Eva produced a good overall geometry with no weird shapes or missing pieces, but the scan result was lacking detail. This was especially obvious in the sesame seeds, which were lacking depth in the mesh. It also had a great speed, as models are generated in real-time. However, the texture it generated and the integrated lighting were horrible for food, creating a very high contrast texture making the food look unappealing. This, combined with the high price of €13700, makes it an unattractive solution. As the price makes it impossible for restaurants to have their own scanner, and the results it gives are unusable. However, it might be possible that with lots of tweaking and custom settings that the visual results could be improved.

The TU Delft only had the Artec Eva available. There are lots more handheld or portable white light scanners, so no definitive conclusions on the whole of these scanners can be made. Considering however that these scanners are more often used for situations where precise accuracy is needed and texture is less relevant, most other scanners likely have similar cons. Nearly all all-in-one portable scanners cost at least €1000, making it still too expensive to place one at each restaurant.

Photogrammetry using a smartphone camera gave acceptable results, the food looks realistic but still contained some small errors in the geometric mesh. Reconstructing the model takes a few hours and some manual work, but this potentially can be automated and sped up with cloud computing power. It struggled with the white featureless plate, which is a common issue with photogrammetry. Potential solutions for this are discussed in the 'limitations' subchapter.

For food 3D models the most important aspect is realism. If the final model looks like plastic, is discoloured, or has huge artefacts, it is unsuitable for presenting on a menu. The concept envisions every restaurant having their own 3D scanner, as this dramatically lowers the cost per scan and makes the concept scalable. More details on why each restaurants needs their own scanner are explained in the next chapter.

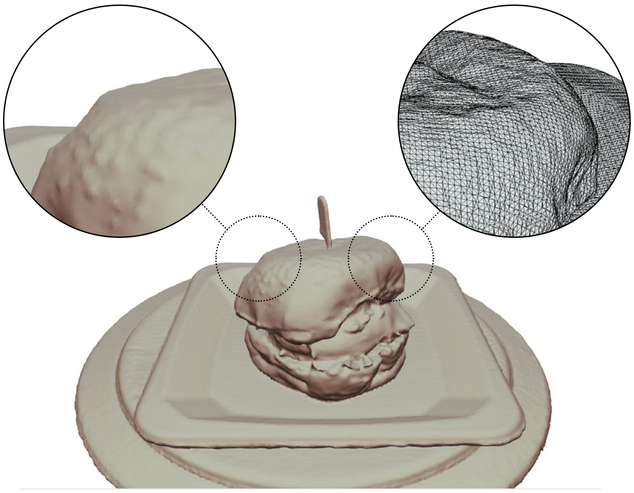
With the cons of photogrammetry more easily overcome, photogrammetry is the way to go for now.

Fig. 4.1: Scanning the burger using the Artec Eva

White Light Scanning

Artec Eva	Model
Handheld Scanner	698K triangles
€13700	4096x4096 texture

Pros	Cons
Instant results	Expensive to purchase
Good geometry	Details get smoothed
	Bad texture
	Bad integrated lighting



Photogrammetry

Apple iPhone X	Model
Smartphone	435K triangles
€1159	4096x4096 texture

Pros	Cons
Readily available	Creating models takes time
Great texture	Acceptable overall geometry
	Issues with featureless surfaces

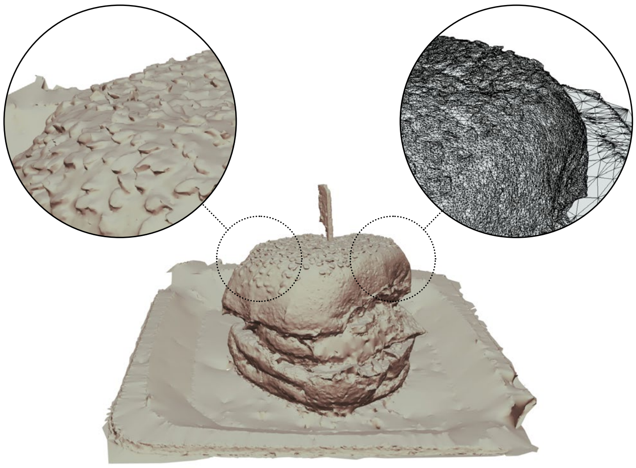


Fig. 4.2: Comparing white light scanning with photogrammetry

Photogrammetry process

Below, the general process for photogrammetry is explained. Some software solutions might automate some steps in the progress, skip some, or have extra in-between steps.
The process can be broken up into 3 parts: pre-processing, processing and post-processing. Each part preferably requires their own set of tools and software.

Automation

Automation of this process would eventually be necessary to make the concept feasible, as the labour costs associated with a manual photogrammetry process would be too high for restaurants according to their opinion on the price during interviews.

As restaurant staff would not know how to handle a camera correctly for photogrammetry, nor have the time to take 50-100 photos of each dish, the scanning is the most important step to automate first. With the corrections step and the whole processing part to be automated later. Post-processing however is the hardest to automate, as cleaning up a 3D model requires a trained 3D artist to both spot the mistakes

Pre-processing

The scanning for photogrammetry involves taking photographs of the object to be scanned. These photos will need to be taken all around the object to ensure every part of the object is visible in multiple photographs.
Next to a camera, other optional attributes such as a tripod, a turntable and a studio tent can be beneficial in creating better photos and speeding up the process.
Especially for food scanning this setup is very important to do right, as lighting plays a big role in food photography. This will be more elaborated in next chapter '4.2 Building The Scanner'.

Resulting from the previous step is a photoset, often around 50-100 photos of the object that is to be reconstructed. It is likely the camera settings were not perfect, the exposure or the white balance might have been off or some shots are out of focus. In order to get a good visual end result, it is best to fix the photos before going to the next step and to delete any unsuccessful photos.
If the photos are taken without a clean featureless background, another necessary step would be to mask out the background for each of the photos

After loading the corrected photos into photogrammetry software of choice, the first step is to align the photos. The parameters for this step should be set according to the amount of overlap between the photos, the complexity of the model, what is in the background, and whether markers have been used.
The software will then try to establish where in 3D space the photos were taken and position them relative to each other. The feature points detected in multiple photos will make up a point cloud and can give a rough visual estimate whether the software succeeded in aligning the photos correctly

and know how to fix them. It would be best to minimise or prevent the need for model cleanup, by making more or better photos and allowing the software to run slower algorithms that increase the accuracy.

Processing

Post-processing

After inspecting the point cloud from the previous step to see whether it resembles the scanned model, the process can be continued. It is possible the alignment went wrong, and the point cloud represents a garbled mess. Which was the result of too few photos, bad quality photos or wrong alignment settings.
When continuing, the reconstruction step will use the points in the point cloud to form a geometric mesh of the object consisting of small triangles.
This step is by far the most time consuming in the process, and depending on the quality setting could an hour to nearly a full day when ran on a regular laptop.

When the geometric mesh has been generated it should be the shape of the object you scanned, but it will be completely grey. Small holes or mistakes can be expected, especially with very thin surfaces (like a leaf of lettuce) or areas that were occluded. Any holes would best be fixed at this stage, while other imperfections can be solved later.
When continuing to texture, the software will use the original photos and their location to project them on top of the geometric mesh, wrapping the mesh to cover every part with a piece of one of the photos. Resulting in a textured model being created.

Any small mistakes still left in the model can be cleaned up afterwards, preferably in a software program specialized for 3D sculpting. This is a step that cannot be easily automated, as it requires someone with the skills to recognize what are still mistakes in the model and the knowledge how to fix those.
This step can be very time consuming, so it is better to opt for more photos or a longer computing time in order to achieve better results, than to fix them afterwards.
The end goal of this step is to get to a model that would be presentable, restaurant visitors want to get a sense of what they're going to get and will not notice small mistakes.

Limitations

While a lot can be done to improve the photogrammetry process to get good looking results, there are some general limitation to photogrammetry. Due to the way the technique works mathematically, some objects cannot be (perfectly) scanned, such as featureless surfaces, transparent surfaces, shiny surfaces or very thin surfaces. However, there are some techniques to overcome these limitations.

Featureless surfaces

These are surfaces where there is little to no difference in colour throughout the surface, see the plate in figure 4.3. With only very slight colour differences throughout the plate, there are not enough feature points for the software to detect in the photos. Since the software is dumb and does not know that the white colour in the images is a plate, and it has no knowledge about that plates are smooth, slightly curved and often round, it will try to recreate the plate solely on what it sees in colour data. Resulting in a very rough plate surface.

There are some solutions for this problem: one way is to get rid of the featureless surface, either by using a textured plate for food scanning, or by sprinkling spices or sauce over the plate to give some extra feature points. Another solution would be to combine photogrammetry with another scanning technique, such as structured light 3D scanning or laser scanning (see chapter 2.3). Rather than two scanning methods, it is also highly effective to use a projector to project a noise pattern over the object (Koutsoudis et al., 2015), and take two sets of photos. Using one set for reconstructing the geometric mesh and the other for generating the texture.

Transparent surfaces

Transparency is the most problematic, whilst also being a featureless surface it shows feature points of the object behind the transparent surface, often refracted because of the transparent material. Photogrammetry software will try to match these feature points behind the transparent object, which might be incorrect due to the refractions, resulting in the object behind the transparency being recreated (incorrectly).

A solution would be to spray over the transparent surface with a matte spray, and later manually add a transparent material to the model. But this does not work well for food items, as you cannot serve them anymore. Few other solutions unfortunately exist, and for food photogrammetry these other solutions also are not perfect. Making the best solution to recommend restaurants not to use transparent plates or food.

Shiny surfaces

Shiny surfaces reflect the light that hits them, creating bright reflections in the photos and losing details in these parts. These surfaces can be fixed using the same methods for transparent surfaces, but other better options are available to eliminate the reflections.

The reflections are created when a hard light hits a shiny surface, using a diffuser on the light source will scatter the light rays and give a softer light, more on this in the next chapter.

If the light source cannot be defused (enough), another solution could be to use a polarizing filter. As reflective surfaces polarize the light, these filters can block out just the reflections in the photo (see figure 4.4)

Fig. 4.4: Polarizing filter

Fig. 4.3: Featureless plate with a shiny lobster

Fig. 4.5: Transparent and shiny glass plate with some reflections

Software

There are a plethora of photogrammetry applications available that take you through the steps detailed in the previously described photogrammetry process. These applications can be divided into two main categories: mobile apps, and desktop applications.

Mobile apps

Mobile options often automate many parts of the whole process, for better or worse. Often requiring the user only to walk around the object to be scanned, with the app open pointing the camera at the object. After doing that, it will give you a 3D model a few seconds, minutes or hours later.

As of now there were only 3 photogrammetry scanning apps available for iOS that did not require extra hardware. All three were tried: Trnio, Qlone and Scandy.

They are all cheap to use, where Qlone and Scandy charge around €1 per model for savings the models, and Trnio costs a one-time fee of €3,49.

While initially tried on non-food subjects for some test shots, a food setup was made to compare these applications with each other. A small plate has been filled with different types of food, each with different textures and complexities. The results of this test can be seen in figure 4.6.

As can be seen from the test results, all mobile options turned out horrible. This was similar for other objects scanned using these apps earlier. This means these apps are unusable at this stage, especially for food. While demos on for example Qlone's own website look good, none of the scan results came close to those results. Likely requiring a very controlled setup to achieve results like they did themselves.

Developments in this area are growing fast though, and the cameras in smartphone are good enough for photogrammetry (as was shown in the previous the Sodexo burger scan). It is likely just a matter of time before a phone app comes along with on-device or cloud rendering that gives similar results to the available desktop apps.

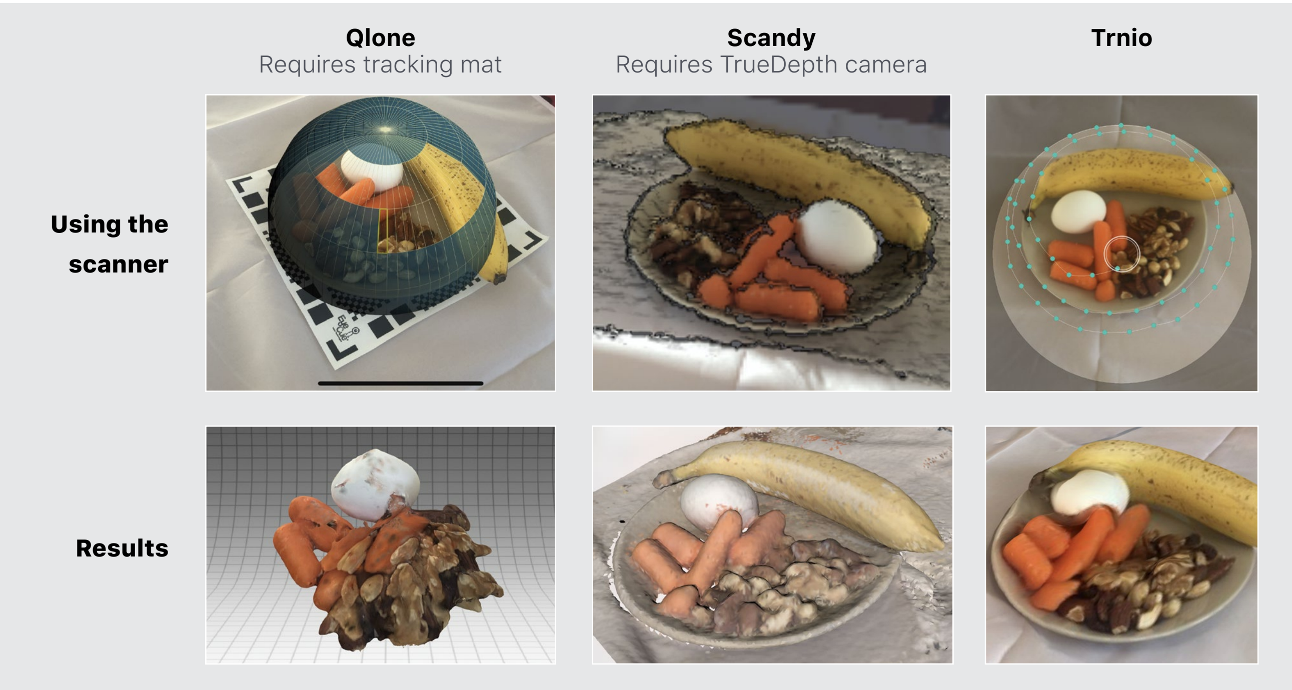


Fig. 4.6: Comparison of mobile photogrammetry applications Qlone, Scandy and Trnio

Desktop applications

On desktop the most options of photogrammetry applications are available. Ranging from free open source programs to very expensive specialized software. Without any prior knowledge of what should be expected from these programs, it was best to limit the scope to trying just 2 of them and comparing the results. As creating models in normal quality from a photoset of 100 photos could take as long as 10 hours.

Having searched the internet about photogrammetry and the apps available there were two apps that seem to be used most by professionals: Agisoft PhotoScan and RealityCapture. Both these apps come with a plethora of features, both are aimed at creating textured 3D models through photogrammetry, and both have options for automating the whole process through custom scripts (which might become a requirement in the future).

Throughout the project various models were created alternating between both these software options, as there initially was not a clear winner which one was better.

All the created models can be found in Appendix C.

Comparing these two applications, there is very little visual difference in the results. Both software options sometimes get the geometry wrong, add extra geometry (often around the plate or thin objects like a leaf of lettuce), or leave holes in the mesh. The best result in the end for fixing these mistakes turned out to be taking more and better photos. Adjusting the settings in the software only had very little impact. Also increasing the quality from normal/high to ultra high gave very little improvement on these mistakes, and only seemed to increase the detail and accuracy of already accurate enough parts.

In terms of speed there was a big difference. RealityCapture managed to be up to 5x faster than PhotoScan for a quality setting that generated similar results. Which is impressive, as RealityCapture was initially released in 2016, whereas PhotoScan was already around since 2010. But while it was a lot faster, RealityCapture lacks some smaller features PhotoScan has, and price-wise the professional command line edition of RealityCapture (€7500/year) is a lot more expensive than PhotoScan's (€3000 one-time). Making PhotoScan the better option to buy in the future.

Fig. 4.7: Agisoft PhotoScan being used to recreate a croissant from 109 photos

Model shading

When viewing these 3D models generated by the photogrammetry software, there is one major aspect to take into account when rendering this 3D model in other software: the shading that is applied.

A standard practice for showing 3D models is to put a light on the model so that it will generate shadows and look realistic. While this might sound desirable, this is intended for computer generated models that have fake materials. When scanning things with photogrammetry the object is already illuminated by the lights in the scanning setup. So the final texture that is applied to the model already contains shadows and highlights from the scan. Since no information is captured about how reflective each of the ingredients of a meal is, adding shading to a photogrammetry model would make food models look like they are made out of the same material/ingredient. Next to that, the shading will also greatly enhance the visibility of small bumps or mistakes in the mesh of the model, as they will cast a shadow because of the added lighting (see figure 4.8).

This is something to pay attention to when using the 3D model within an app, sharing it with someone or putting it on a website. Adding shading is often the default behaviour, which will need to be turned off to ensure the model looks good. Unfortunately not all 3D programs allow you to do this.

Fig. 4.8: Difference between shading on and off

In conclusion

Photogrammetry turned out to be the better option for scanning food items compared to structured light scanning, so further experimentation with photogrammetry solutions was done.

Comparing automated smartphone apps with professional desktop applications there was a major difference in quality, with the currently available smartphone apps giving unusable 3D models.

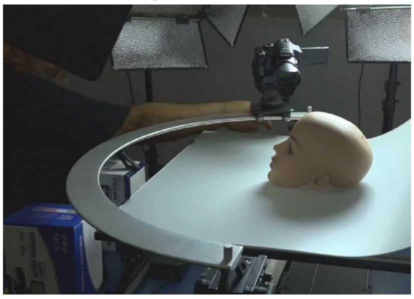
Proper 3D models were created using professional desktop software Agisoft PhotoScan and RealityCapture; during the pilot test (see chapter 5.1) users rated the quality of these models with an average of 5.7 out of 7.

A lot can still be learned in photogrammetry software, as these applications offer many small features that can improve the quality of the models even more. Also the automation of the model generation is something that definitely needs to happen at one point, as even when experienced with the software it still takes more than 1 hour of manual labour per scan to get a good result.

4.2 Building The Scanner

To create the 3D food models discussed in the previous chapter it is beneficial to have a scanning setup that can (partially) automate the photographing, as well as ensuring you get adequate photos that result in a realistic 3D model after processing. The quality of the 3D food models is important to ensure the model looks appetizing, and a fast scanning method is preferable to prevent food waste, so that a warm dish can still be served after scanning. This chapter takes a look at the aspects that are important for this, and presents the prototype scanner that has been developed. When scanning objects using photogrammetry, there are 3 main ways this can be accomplished: Moving the camera, rotating the object or instantly capturing the object. These methods are compared in detail below.

Moving the camera



Hold the object in place, rotate camera
This is the most common way photogrammetry is done. Where people often walk around an object, photographing it from as many angles as possible. There are also ways where the camera is placed on a rig and sometimes automatically controlled to ensure there is enough overlap between photos.

When to use: Cheap solution needed, object cannot be rotated

Disadvantages: Images can be moved if taken too quickly, camera might block the lighting, background changes (but according to object)

Rotating the object

Hold the camera in place and rotate the object
The other way around would be to rotate the object and keep the camera in the same place. This is most often done using a turntable where the object rotates around the Y-axis. After a full rotation on the turntable either the camera should be placed at a different height & angle, or the rotated object should be rotated along its X-axis or Z-axis.

When to use: Cheap solution needed, need for camera tripod images, easier when using a light setup

Disadvantages: Object must be able to rotate, can be time consuming, lighting on the object changes when rotating, background stays the same (only problematic with a busy background)

Instant capture

Hold the camera and object in place, using cameras all around
By far the quickest way to do photogrammetry is by keeping both the camera and object in the same place, but this can only be achieved using lots of cameras to ensure every angle is captured. Often a minimum of 70 cameras is needed to get usable results when doing a 360-degrees capture, while 100+ cameras would actually be recommended for such a setup (Twindom, 2018).

When to use: Capturing moving objects (e.g. people, animals)

Disadvantages: Expensive (Needs preferably 50+ cameras. With DSLRs this costs you €25k, with raspberry pi €2500), difficult to setup, needs a lot of space.

Requirements

To make the concept scalable the aim is to produce a cheap scanner (<€500) that can be left at restaurants permanently. Kitchen staff likely will not know how to operate such a machine or will not have the time to interact with it, therefore the scanner should ideally be a 1 button press solution to generate the entire scan, where it will send the photos to the cloud for processing and post-processing.

Scanning speed can be a big requirement if restaurant still want to serve their hot meals after scanning, reducing the scanning time to a maximum of a few minutes. However, a few minutes would still be too long for meltable foods such as ice cream, as was discovering during the scanning of desserts. For this, the scanning time would need to be closer to 1 minute to prevent too much melting. As when the ice cream melts during the scan, the meal is being changed visually, resulting in photos that are more difficult to align.

In order to scan within this timeframe there is an absolute requirement to make the scanner operate automatically. As 100+ photos would need to be taken within 60 seconds. To make the machine fully automatic, the best option would be using multiple cameras each at different angle, and a turntable to rotate the meals. Combining the second (rotating the object) and third (instant capture) techniques.

To do this with a single camera it would require an automated mechanism that can move the camera up and down to a different angle. To validate whether it is time-wise even feasible to use just one camera, a speed test with the developed scanning turntable will be performed later on.

The quality difference a better camera could have is also debatable whether that would have an added benefit. As later on in the project it became clear that the future of SeeFood will be bring your own device (BYOD). Where customers can access the app from their own phone. This would add a requirement for the 3D models to be heavily optimized to achieve a small file size. This optimization would likely get rid of most of the finer details, making the visual difference between a scan with an expensive and a cheap camera a lot smaller.

From interviews with restaurants owners other requirements for the scanner were given. In general it needs to be fool proof, as the kitchen can be a very hectic place where accidents can happen. So it should not be easily tipped over, break when bumped into, and be easily cleanable.

Every restaurant has different requirements for how often they want to scan and the amount of space they have available in their kitchen. If a restaurant only wants to use it every few weeks it often cannot permanently occupy kitchen space. The design would thus need to be folded up quickly and quickly setup again when needed. It should be easily cleanable, perhaps even having plastic or a cover around it to prevent it becoming too dirty. But in the end these requirements all boil down to that there should be as little as possible that could go wrong, which might cause the scanner to break.

These requirement would mostly be important for a future version of the scanner. As developing the perfect scanner for restaurants will be out of scope for this project.

A prototype scanner was developed, which would allow for easier and better scan results before having the desired scanner. The rest of this chapter goes into detail about the development of this prototype scanners, and the learnings during this development that further define the requirements for future versions of the scanner.

Turntable

For the design of the turntable, multiple existing DIY designs have been considered. Based on available parts, a preference for a small turntable, and a need for it to be able to carry a few kgs, the decision has been made to base the scanner on Urban Exile's design of a 3D scan turntable (Urban Exile, 2017).

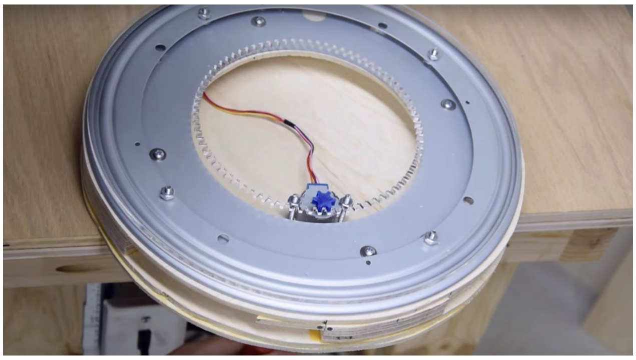


Fig. 4.9: Urban Exile's 3D scanner turntable design with Lazy Susan ring

This design formed the basis for how the scanner was going to look. Using a Lazy Susan with an internal gear attached to it, driven by a stepper motor with a gear attached.

Multiple iterations of this scanner were made, fine tuning the gears to adjust for tolerance in the Lazy Susan. Special thanks to Sagar Dahal for helping me with the development of this scanner, by creating all the gear calculations, making the lasercutter files, assembling and glueing the scanner, and making and testing multiple iterations of the gears. The result of this is the scanner as seen in figure 4.10 below. The lasercut files to create this scanner can be found in Appendix D.

Electronics

For the electronics, a NEMA 17HS4401 stepper motor was chosen to drive the turntable. This is a small stepper motor with 40N.cm holding torque. But since the Lazy Susan's ball bearings should eliminate most of the friction, requiring very little torque to get the turntable spinning. While no calculations have been done to verify this, the motor did in the end turn out to be powerful enough.

The stepper motor was hooked up to a small Arduino controlled circuit to drive the logic behind it. It was programmed to operate using microstepping, this means that rather than using the standard 200 steps per revolution it would use 400 (1/2) or 800 (1/4) or a multiple up to 1/32 to make a full revolution. This greatly increases the accuracy and reduces vibrations, but at the cost of losing torque. Vibrations were unfortunately a big issue, when not using microstepping the whole scanner would vibrate, even causing objects placed on top to start moving. This turned out to be a mistake in material choice, as metal and wood are resonant materials that greatly amplify the vibrations of a stepper motor (BBAstroDesigns, n.d.). Adding isolation material between the stepper motor and the wooden base would have solved this, but the stepper motor was already glued in this scenario. Luckily, setting the stepper motor microstepping to the maximum of 1/32 brought the vibrations down to an acceptable level.

The turntable is programmed to turn 1/x of a total rotation, then flash an infrared LED to make the camera go off, and loop this until a full rotation is completed.

The turntable also features a detachable top plate. This was an intentional design choice, as that would make it possible to use a bigger or smaller top plate, or use a different color plate so that it would be contrasting with the color of the plate of food. Making it easier to automatically mask out the turntable in the photographs. Further details about the electronics, the Arduino code, and the schematics can be found in Appendix E.

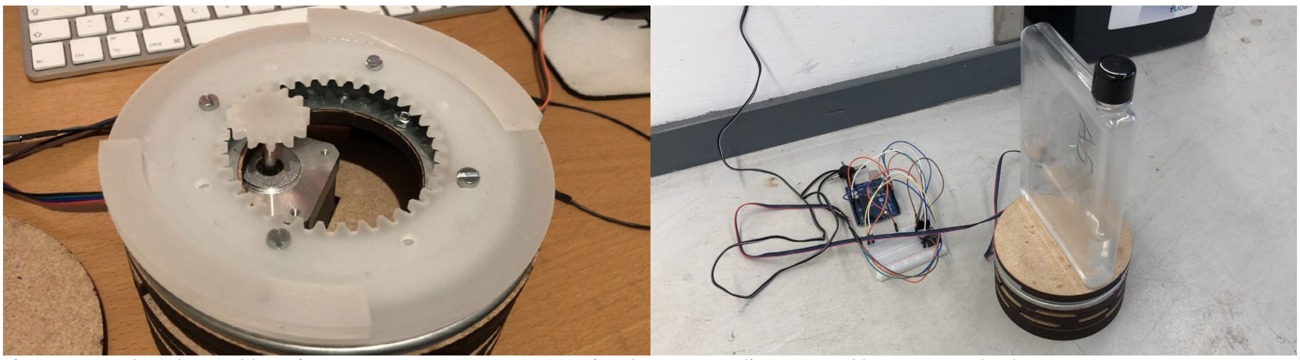


Fig. 4.10: Developed turntable, using a stepper motor, Lazy Susan ring, lasercut acrylic gears and lasercut wooden base.

Cameras

As was learned from creating 3D models, the photo quality is extremely important for getting good results using photogrammetry. While a proper DSLR camera would give the best results, decent results can still be achieved using much cheaper cameras. However, those cheaper cameras are way less versatile, so all the camera settings need to be spot-on and the object needs to be properly lit. The quality would still be less than with a professional camera, but with a future requirement of having small file sized models this quality difference would hardly be noticeable anymore.

Using multiple cameras could significantly raise the price of the scanner. Therefore, DSLR cameras (which start around €500) would make the entire setup too expensive, raising the need for a cheaper camera.
The first option seems to be smartphones or tablets, as these feature good cameras and for the restaurant context the staff likely could use their own phones or tablets if they were to go for a digital menu on tablets. A major issue however with these devices is the lack of control over the camera settings, so a specialized camera app would need to be developed. When going for a multi-camera setup, you ideally want the exact same lens and camera sensor on each of them, as different lens distortions could cause issues with aligning photos using photogrammetry. Thus, combining different phones would not work well.
A camera that is likely to be a good fit is the Raspberry Pi 8MP camera (see figure 4.11). This camera costs just €29 and can be controlled using a €5 Raspberry Pi Zero.

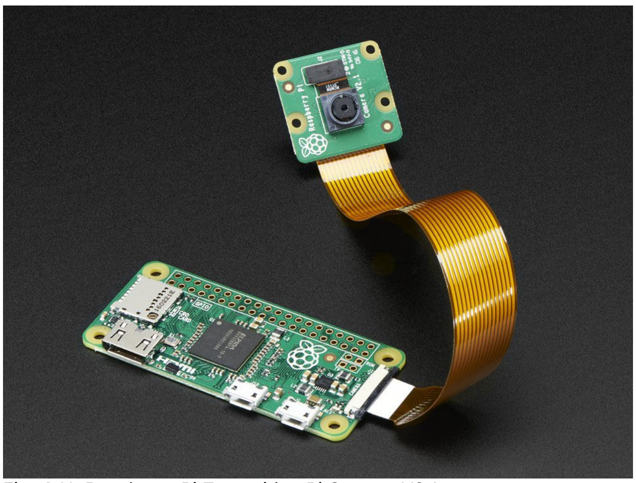


Fig. 4.11: Raspberry Pi Zero with a Pi Camera V2.1

Other photogrammetry rigs have previously been developed using Raspberry Pi cameras for the whole rig, such as the Pi3DScan. Validating that this camera can indeed be good enough for photogrammetry, but food photogrammetry and full-body human photogrammetry might have different quality standards.

An issue when placing multiple of these cameras over the object might be the lens of the camera fogging up, when hot food is being scanned. If this occurs in practise, a small fan might need to be installed close to the camera to blow away any steam.

Focus & Aperture

Everything needs to be in focus as much as possible, as parts of an object that are of out focus will be blurred, losing the detail and contrast that is needed for photogrammetry to work. The aperture, the size of the opening of the lens, determines the amount of the photo that is in focus. Unfortunately this cannot be changed for the Raspberry Pi camera, but for other cameras this setting should be as high as needed to ensure everything is in focus.

ISO

The ISO is the light sensitivity of the camera sensor. The higher the value, the more sensitive to light it is. For photogrammetry the camera’s ISO should, if possible, always be set to its native base value, as this value would give the lowest signal-to-noise ratio (Martinec, 2008). As noise could lead to mistakes when matching points between photos.

Shutter Speed

When changing the aperture and ISO, the shutter speed of the camera should be set accordingly to ensure a proper exposure. Opting to choose for a turntable this setting is not so important, as the object and the camera both are completely still when each photo is take.

White Balance

This should be set to the color temperature of the environment, when using artificial light the lamps often have this value indicated on them. Setting this right ensures that the final 3D model has natural colors.

Lighting

Proper lighting is extremely important, not only for photogrammetry to achieve better results, but also for food photography to get appetizing photos.

Soft Light

The most important aspect of light is the hardness of it. Hard light means that the light source hits the object directly, this creates harsh shadows and bright highlights. Soft light is the opposite, where light has been diffused by bouncing off or through other objects changing the direction of the light hitting the object. Resulting in an equal amount of light over the whole subject (see figure 4.12).

The best way to create this soft light is to use some diffuser material. For example, sunlight passing through some clouds will create soft light. When using artificial lighting, such as a LED strip, a material like frosted acrylic glass can be placed close to the light source to make the light softer.

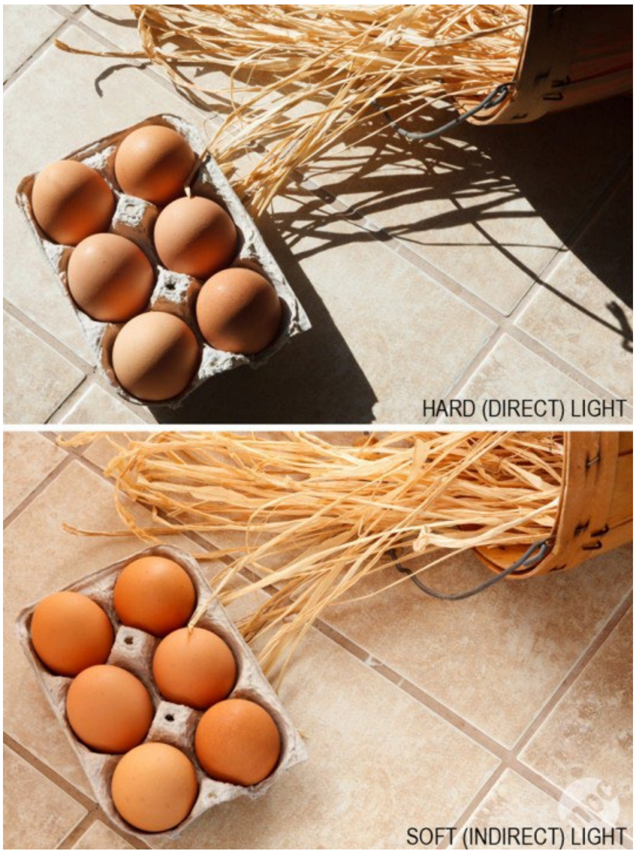


Fig. 4.12: MyPhotoCentral 2015. Difference between hard and soft light.

When only using 1 or 2 light sources even soft light will not create a perfectly evenly lit subject without objects around it reflecting light onto the sides. In order to control this indirect lighting, and to prevent other unwanted light sources from polluting the image, a reflective photo studio box is a good solution.

From testing with such a photo studio box, the bottom of a plate would be underexposed, as too little light would reflect to that location. To prevent this in future scanner setups, the turntable would need to have integrated lighting to add some extra illumination from the bottom.


Fig. 4.13: AmazonBasics portable photo studio box

CRI

When choosing an artificial light source, the CRI (color rendering index) is important. This value describes how well a light source is able to reveal the actual colors of an object, with a score of 100 meaning a perfect light source that would be identical to daylight. An incandescent light bulb would achieve this perfect score. Those lamps produce a lot of heat, making them unfit to use for SeeFood, as it would accelerate melting of ice cream. LED lights often start around a CRI of 80, but more expensive high-CRI LEDs are available.

Fig. 4.14: Difference between a low and high color rendering index

Lasers

As mentioned in the previous chapter, the issues of featureless surfaces can be overcome by projecting patterns on top of these surfaces. However, as the photo studio box produces a lot of light already, a pattern from a projector would be quite dim. Therefore, a choice has been made to use small laser pointers to project a dot pattern over the dish, as even in brightly lit environment the laser dots are still clearly visible to the camera (see figure 4.15).

The lasers can be instantly turned on and off digitally through an Arduino or Raspberry Pi, so at each angle one photo with and one without the lasers can be taken. The pictures taken with the lasers on can be used to generate a better mesh of the model, as more feature points can be detected in the featureless parts of a photo. This way the scanning quality can be increased.

Cost

A quick cost estimation for the envisioned scanner has been made, based on costs of the developed turntable, intended cameras (Raspberry Pi camera), photo studio box and lighting requirements. The total cost would come down to around €480 per scanner. For a full breakdown of these costs please see the financial model in Appendix F.

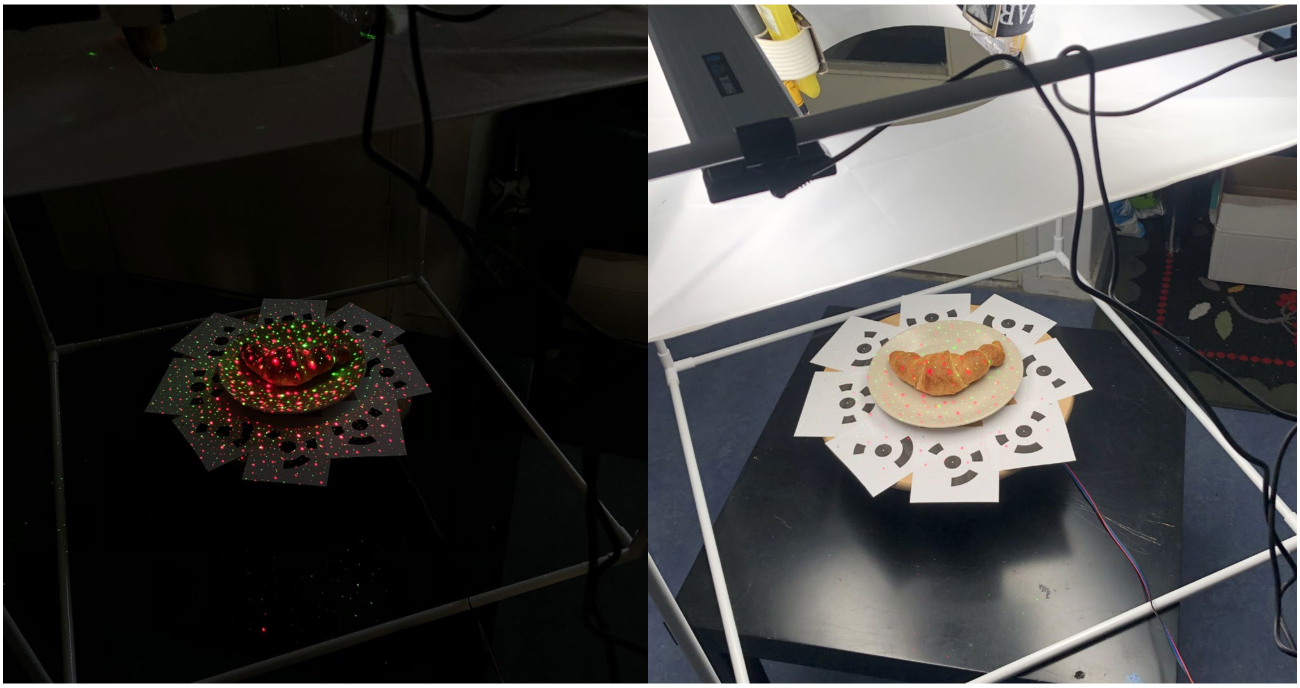


Fig. 4.15: Using lasers to display a dot pattern on an object.

Testing the scanner

With the previously developed and specified parts, a prototype of the complete scanner was put together. Made possible with the help of the TU Delft Startup Voucher funding some of these parts.
This prototype was used to scan the meals later used for pilot testing. During this scanning the speed of the scanner was tested and some other issues came to light.

Scanning speed is essential if restaurants want to scan meals that they can still serve afterwards or want to scan meals that melt quickly like ice cream. To test how quickly a meal could be scanned, various speeds of the scanner were tested. A speed of 10 rotations per minute turned out to still be acceptable as the vibrations resulting from this speed did not seem to move the meals, but they did wobble a bit when turning. Theoretically at this speed a full 360° scan could be done in 6 seconds. But the scanner still needs to stop for the camera to take a picture and not fill up the camera's buffer.
As the food wobbles when rotating it is undesirable to take a picture immediately when the turntable stops the rotation. As some parts of the food might still be moving a little bit before returning to their original position. A 0.5 second delay was chosen before triggering the camera, this captured photos without any movement in the food. Another 0.5 second delay was added after the camera trigger, to account for a delay in the camera processing the trigger signal and the time it takes to take the photo (1/20 of a second in this testing setup). Using a total of 30 photos per rotation, the scanning time for 1 full rotation was brought down to 36 seconds.
While it might seem possible to speed this up even more by optimizing the delay before and after the camera trigger, the camera buffer clearing time is another issue that should be accounted for. While many digital cameras are able to capture multiple photos per second, they often are only able to do this for a few seconds. Then the buffer that is saving the captured images will be full and the speed will be dependant on the speed the camera can write the images to the memory card. The camera used during testing this setup (Canon 5D Mark II) has a buffer of 13 RAW photos and a writing speed of around 1 second per RAW file, also limiting the speed it could shoot pictures to around 1 per second.

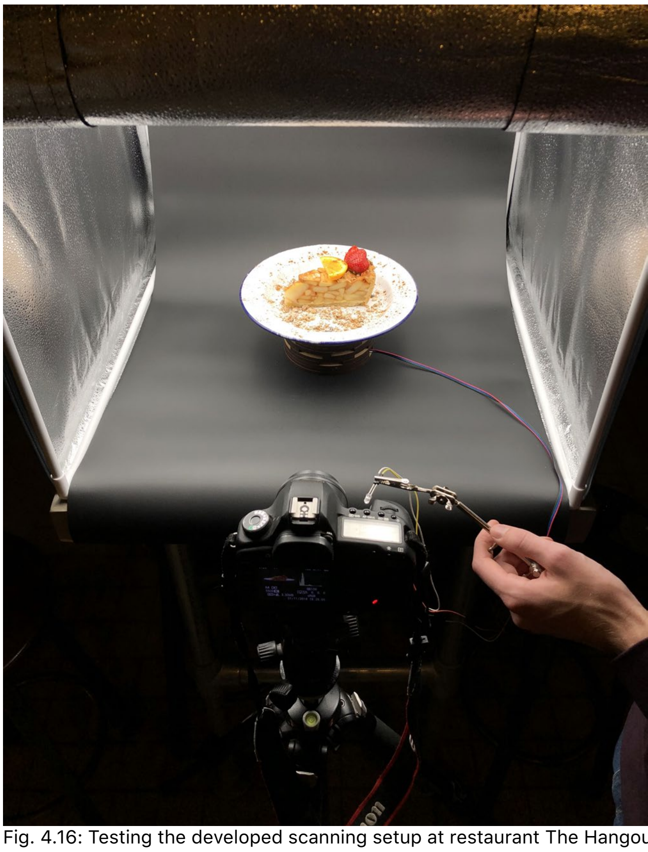



Fig. 4.16: Testing the developed scanning setup at restaurant The Hangout

Future Steps

The current scanner that is developed is still very much a prototype, and is unsuitable for usage by a restaurant on their own. But from developing this scanner, it became clearer of how the scanner should be in the future.

Design

As was learned from interviews, restaurants do not have the space to put the scanner permanently in their kitchen. Therefore it should be designed to be foldable and not take up a lot of space. However, this might lead to restaurants deciding not to scan some dishes, as they do not want to deal with setting up the scanner and storing it again for just 1 scan.
Rather than restaurants hiding the scanner it could be an idea to design the scanner as a beautiful and interesting object, so that restaurants would place it somewhere in the open for customers to see. There would be no need to have to store it, and accidents that might happen like in a hectic kitchen are less likely to occur.
This design tactic was famously applied to routers a few years ago, where in order to get the best connectivity users would need to place the router in a prominent visible place in the middle of their home. In order to stimulate users to do so, manufacturers started designing pretty routers (Barrett, 2016).

Automation

For restaurant to be able to scan their own meals, and to get rid of the manual labour costs of scanning, the whole scanner setup and photogrammetry process needs to be automated eventually. The way this could be accomplished is visualized in figure 4.17.

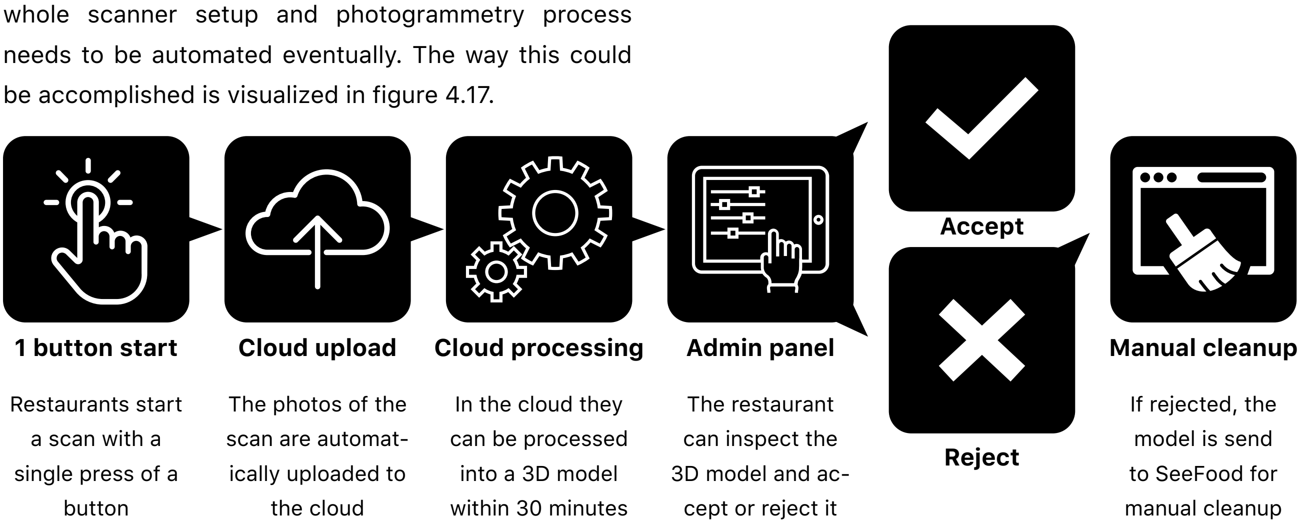


Fig. 4.17: Automation of the scanning and photogrammetry process

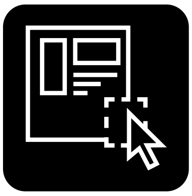
4.3 Prototyping an AR App

To be able to show restaurant visitors and restaurant owners how an augmented reality app with 3D foods models would work, a prototype needed to be developed. Just pictures or videos would not have been enough, as most people are still unaware of the quality of current AR applications and by experiencing it you truly understand the effect and benefits of AR.

Prototyping options

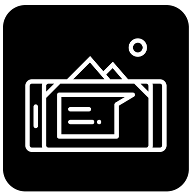
In order to develop a prototype application several application to do this have been explored. As was concluded from chapter 2.2 the availability of ARKit (Apple iOS) is currently much higher than that of ARCore (Google Android), therefore it best for the app development to be ARKit-first. This has been taken into consideration when selecting which prototyping options to compare in depth.

The options for prototyping can be divided into 3 categories:



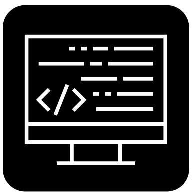
App prototyping tools

Tools for rapidly prototyping (mobile) applications using visual click-and-drag editor. Most useful for testing user interfaces (UI), but often lack programmable logic.



AR prototyping tools

Tools specifically targeted at prototyping AR experiences. This category is still very new, as no tools existed in this space before 2018. So limitations should be expected.



App development software

The software used to develop apps can also be used to create a prototype, a major downside is that it takes longer to achieve the same result as with prototyping tools.

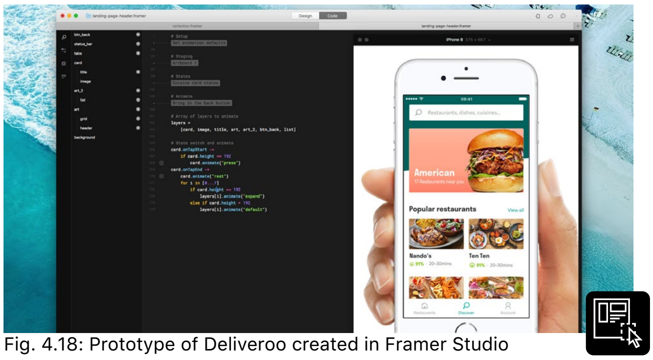


Fig. 4.18: Prototype of Deliveroo created in Framer Studio

Framer X

Out of all the available app prototyping tools, Framer is by far the most versatile, as it allows you to program code in combination with visually creating your prototype app. Under the hood this tool is basically making mobile-website that behave like apps (web apps), therefore limiting the scope of what is possible for web apps to do. Unfortunately, mobile web browsers do not support frameworks like ARKit or ARCore (yet), and current forms of browser-based AR do not work well enough and are only available on some devices.

Verdict: Unsuitable, no support for AR frameworks.

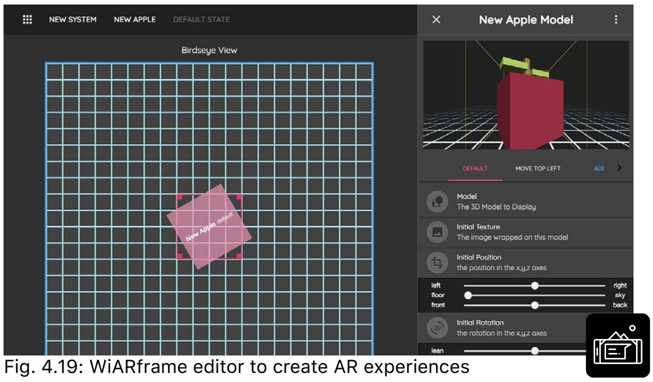


Fig. 4.19: WiARframe editor to create AR experiences

wiARframe

This tool can be used in your browser to create an AR experience, using your own 3D models and defining various interactions. On a phone with the WiARframe app it is then possible to view them. However, when trying to create the SeeFood app the food models would not load properly. And various small other errors occurred, revealing that the tool itself is still very much in a prototype stage.

Verdict: Promising, but did not work yet for SeeFood.

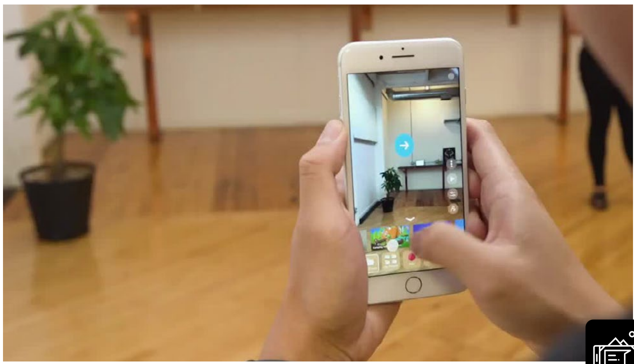


Fig. 4.20: Torch AR app

Torch AR

Torch allows you to create AR experiences while already in augmented reality. The augmented reality view of the world acts as a canvas where 3D models can be placed, and certain interactions can be linked to them. The SeeFood 3D models did load in Torch, but the models appeared shaded, which is undesirable for photogrammetry as this makes the food look fake (more on this in chapter 4.1). As this is also a very new app (2 months old when tested), there was no option yet to turn the shading off, therefore, making Torch not an option.

Verdict: Promising, but did not work yet for SeeFood.

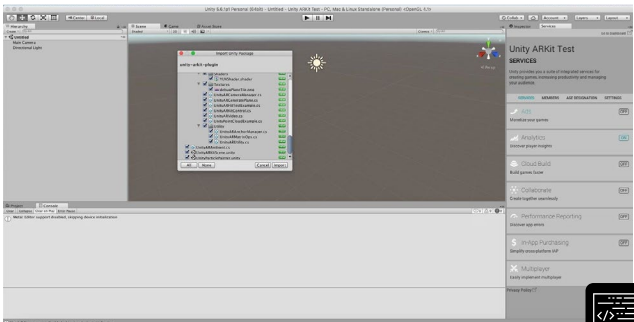


Fig. 4.21: Unity ARKit plugin

Unity 3D

Unity is a full fledged 3D game engine. While mainly intended for video games, its nowadays suited for developing nearly any application that has 3D. In order to develop for augmented reality there are plugins for all the major AR frameworks (ARKit, ARCore, Vuforia, Wikitude). While slower to create something in Unity than with most prototyping tools, Unity comes with a lot of presets that do help speed up prototyping. Because its software intended for complete app development, the only limitation to what can be made is your imagination.

Verdict: Good solution, perhaps the best option.

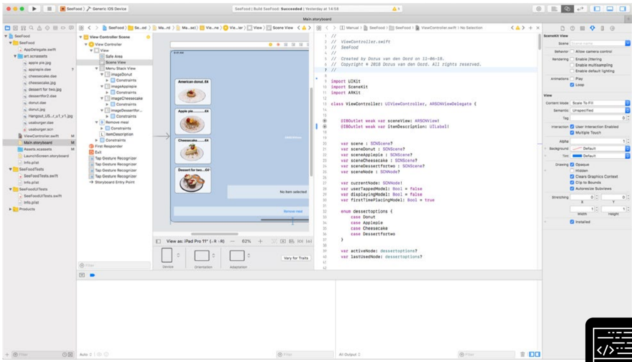


Fig. 4.22: Apple Xcode, an integrated development environment

Xcode

Xcode is the native way of creating iOS apps, it is the official software development suite provided by Apple. Therefore, Xcode will always have the latest features available, and has support for anything an iOS app could do. However, this many options make it a quite complex application and add a steep learning curve for anyone new to the program.

Comparing Xcode with Unity, quality wise there is little difference between choosing Unity or Xcode for a simple AR app. Unity would be a bit quicker: the many presets and a smaller learning curve make it easier to develop a simple app. But the speed difference is not very big compared to the difference of using a prototyping tool (if there were suitable options for AR). Therefore the decision comes down mostly to personal preference, so with an interest for learning Xcode the decision was made to use this for development.

Verdict: Good solution. Chosen to use this one.

Developed prototype

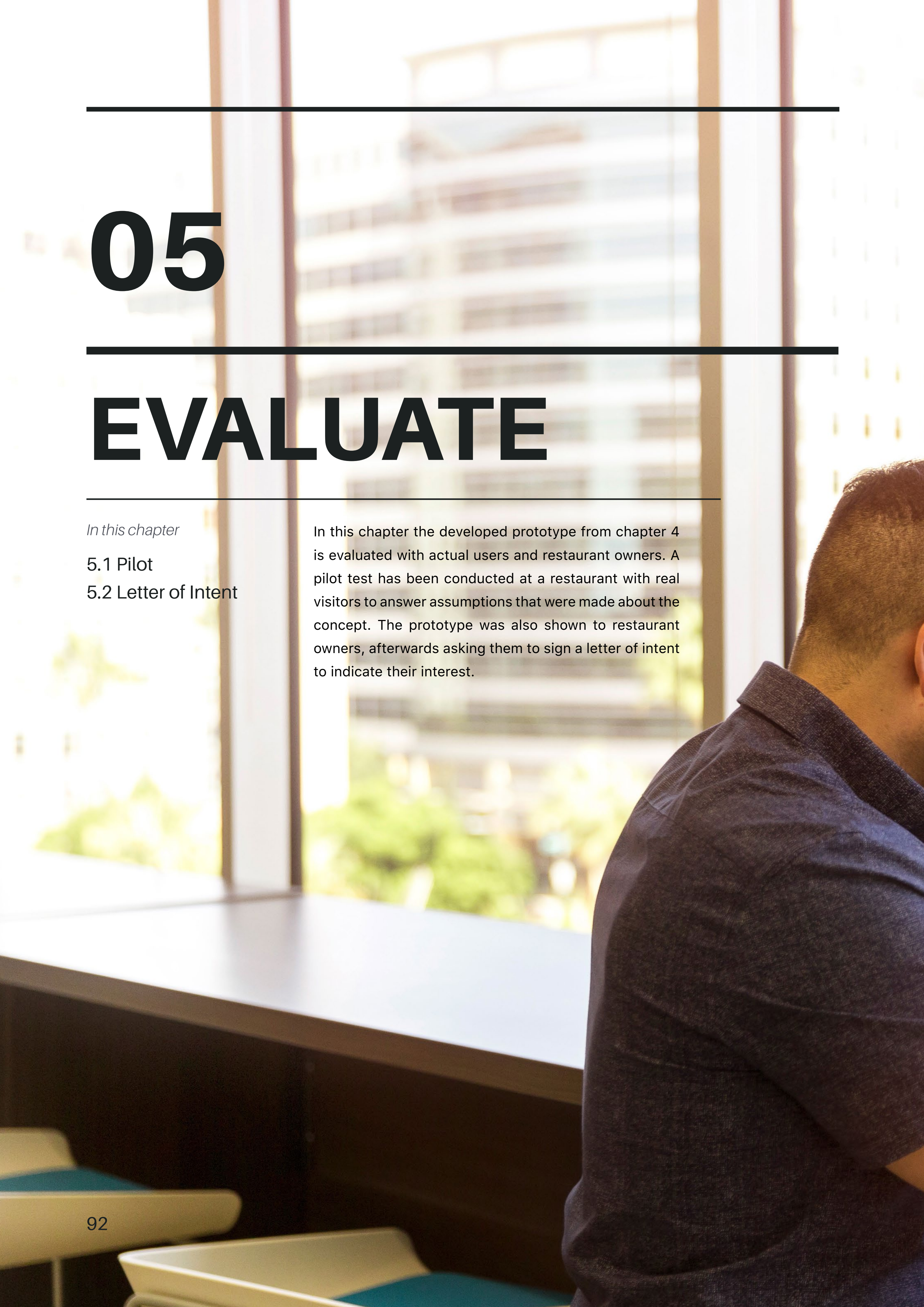
Having chosen Xcode as the software to develop the prototype in, a simple prototype was initially made. This prototype was meant only for viewing one meal in augmented reality. The 3D food model from the scan of The Hangout's USA burger was used for this. This prototype served as the basic proof of concept of how the app should to work, showing the capabilities of what ARKit can do. While this prototype still had many flaws (you could place unlimited meals and there was no way to move, rotate or scale the models) this prototype was suffice to be used during pitches, for gauging people's reactions and showing restaurant owners the promise of what AR can do.

For the final prototype the purpose of the prototype was that it could function as a simple menu for testing in a restaurant. Therefore, it needed to be able to display the meals in AR, show users all the available choices, the prices, and the description of what it is. This way, the prototyped menu would have all the same information as the current menu, with the addition of just the 3D models and AR. Making it easier to compare the effect of these factors.

Rather than scanning the whole menu, a decision was made to only scan the 4 desserts that were available at restaurant The Hangout. As the scanning and recreating the models was not fully automated yet, scanning a full menu would have taken too much time. Additionally, this also would have added extra time to the development of the prototype, as each 3D food model needs to be converted, rotated and scaled before being ready for usage in the prototype.

The final prototype was designed for the 2018 iPad Pro, as this device would be used for testing the app. Designing for a tablet, rather than a phone, also gave an added benefit of not needing to spent time optimizing the layout as there is enough screen real estate to display all the information without blocking the view of the 3D food models in AR.

Unfortunately, Xcode gave lots of issues during development. This was mainly caused by a lack of knowledge and few help resources being available online. These issues slowed down the development a lot. Luckily, with the decision to prototype straight in Xcode it will be easier to keep iterating on this prototype and adding features. Whereas if the prototyping apps were sufficient for this initial prototype, a switch to Xcode or Unity would have had to been taken anyway at a later stage.



05

EVALUATE

In this chapter

In this chapter the developed prototype from chapter 4 is evaluated with actual users and restaurant owners. A pilot test has been conducted at a restaurant with real visitors to answer assumptions that were made about the concept. The prototype was also shown to restaurant owners, afterwards asking them to sign a letter of intent to indicate their interest.

5.1 Pilot

Goal

A small pilot study was set up to further validate the most important assumptions previously made about restaurant visitors. This pilot aims to answer the following research questions:

Q1. Do people prefer to see 3D models of their food over text? Does it increase cravings?
Research has shown that the brain will trigger a dopamine response when viewing food-images, with this response being higher when shown high-caloric foods (Frank et al., 2010). This creates a feeling of hunger and cravings for food. But how do people perceive 3D models of food, do they like them more? Will they increase their hunger? Will they increase their cravings towards the food?

Q2. Do people like seeing their food in AR?
During the validation process when talking to potential users, some indicated they had no interest in using augmented reality. These users however were not shown a demo yet, creating the hypothesis that their previous experiences with outdated augmented reality applications shaped their view on AR. Given that consumer responses to newer ARKit and ARCore applications have been very positive. So, when provided with a proper AR experience, do people want to see their food in augmented reality? Or would they be just as happy with seeing these 3D models just on the screen.

Q3. How do people interact with a digital menu?
Many people have never experienced a digital menu, or only once or twice. What are their expectations about such a menu; what do they expect that is included? What do they like to see included in the menu? Would they prefer a digital menu over a physical menu?

Method

A prototype was developed that was used for running a pilot at restaurant The Hangout, this prototype consists of two parts:

- SeeFood's menu application running on an iPad, suitable to be used at one table by 1-4 visitors.
- 3D scanner that is able to quickly make all the photographs needed to recreate all the available desserts into 3D models.

Location: The Hangout, TU Delft Campus

The dessert menu of The Hangout (see figure 5.2) was decided to be the scanned using the prototyped scanner. The reason for choosing for desserts was because it is an item that does not get ordered often according to the owner. Often selling only 1 or 2 desserts per evening. Therefore, if significantly more people decide to order a dessert during the pilot, that would somewhat validate that 3D models can help increase sales.
The 3D models of the desserts were loaded into the developed prototype application and were made to display the same information as the traditional menu does.

Guests who just finished their dinner were asked if they wanted to participate in a master thesis research about a new menu, and answer a small questionnaire. A total of 13 guests participated in the research.

To set a baseline of what people think of the regular menu, a few initial questions were asked about their opinion on the regular menu. At this point they were not told more than that the pilot test was about 'a new type of menu'. Only after completing the first set of questions, the AR menu demo was shown to them on an iPad Pro. After having seen the demo and experienced it for themselves, they were asked to complete the remaining questions of the questionnaire.
A total of 24 questions were asked, the full questionnaire that was used can be found in Appendix G.

Results

All 13 responses to the questionnaire can be found in Appendix H.

Q1. 3D model perception

During the pilot the 3D models did increase both hunger, cravings for dessert, and how much the menu is liked, compared (see figure 5.1) to the regular menu.
1 person did not like it, saying it *"Seems really cheap"*.
All the others were divided between either not caring so much, giving mostly neutral scores of 4/7, or thinking it is great and strongly liking this new menu over the regular one.

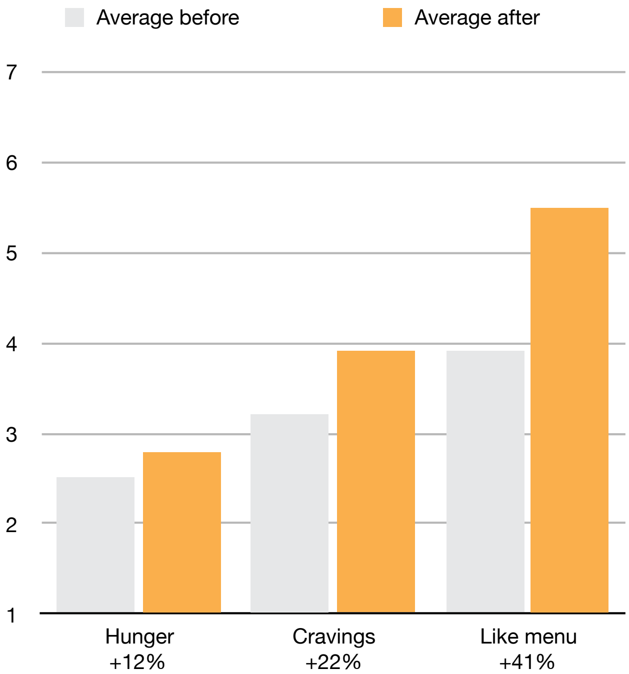


Fig. 5.1: Visitor before and after seeing 3D food models in AR

Q2. Augmented reality perception

Asking the open question "What was your opinion on seeing 3D food models in augmented reality?" in the questionnaire, the answers were overwhelmingly positive. 12 out of the 13 respondents had a positive response to this question.

"Pretty cool!"

"Nice feature and well detailed."

"Really cool feature, definitely helps with the choice."

The same person that did not like the 3D models was again the person who also had a negative experience with the AR aspect: *"Bit cheap looking."*

Q3. Digital menu perception

While a majority seemed positive about the new menu, when asked to choose on a scale if they like the old menu or the new menu, 54% of the respondents gave a neutral score (23% does not care, and 31% has a slight preference for the new menu).
In the optional comments many people indicated that while they liked the 3D models and saw a benefit to

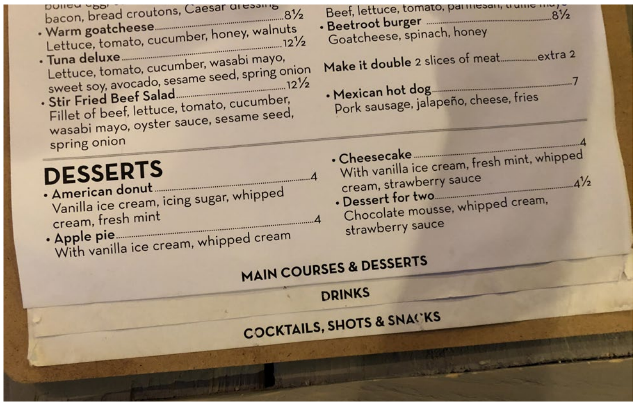


Fig. 5.2: The current dessert options at The Hangout

Pilot Setup

13 visitors

At restaurant The Hangout

10-15 minutes
24 questions

them, they would still like using the regular menu. Saying the regular menu seems simpler or that they do not want to use technology during dinner.

“The 3D model is nicer and more appetising But the old menu is simple.“

“Its nice but I prefer a paper menu.“

“It looks cool, but I’m not too fond of technology in a social setting. A physical menu is less distracting.“

“Not sure if I want to have a tablet during dinner.“

Other findings

Nobody was planning on ordering a dessert at the beginning of the questionnaire, only 1 person responded with 'maybe'. In the end, no one ordered a dessert.

There were only 3 people who indicated they sometimes have problems with the menu in restaurants, while others responded 'no' to this open question. The ones that did experience problems all had different issues with the menu:

"Sometimes too many options makes choosing difficult."

"Yes, setup isn't clear, no index."

"Not so many vegetarian options and really unhealthy desserts."

Discussion

A big limitation of this pilot was the limited sample size. A restaurant can be a chaotic and crowded place during dinner time, and there were little possibilities to approach the people who just finished their main dish to ask them to participate in the pilot. A bit later in the evening turned out the be a better time.
Rather than being a part of the restaurant experience, the pilot was disruptive as it was disturbing people in their regular conversations. Hence, some people were not willing to participate in testing, with it being an evening and they were tired.

Another major drawback was that people were asked to rate both the normal menu as the new menu. While this did make the results easier to compare and more significant for such a small sample size, people could make a good estimate of what was being tested, as they were asked twice how hungry they felt and how much cravings they had for dessert. The participants being aware of this has perhaps steered their answers into a more positive result, rather than reflecting their actual opinion.

While originally planned to be included in the pilot, due to time constraints, there was not a third of fourth menu option. These options would have been a menu with pictures of the desserts and a menu with just interactive 3D models (so no augmented reality). During the pilot study the regular menu with only text was compared to the most elaborate option possible of 3D food models in augmented reality. As earlier research had already shown an increase in cravings when going from just text to showing images, a similar result would have been expected for this scenario too.
A comparison between photos and a 3D model would have been more interesting for validating the value of 3D food models. This is something that should be done in the future.

Fig. 5.3: Testing the prototype of the SeeFood menu application at restaurant The Hangout

5.2 Letter of Intent

The Letter of Intent (LOI) is method often used by startups to validate a product/market fit, testing whether customers are willing to pay for it before the product exists. This is done by creating a letter that closes a deal between two parties, the startup and the potential customer. The customer can express their intent of buying the product when it is available by signing this Letter of Intent, which specifies the deal of what the startup would deliver and what the customer would pay for that.

The best validation for a startup would be actual paying customers, but when there is no product yet and the startup has no track record, the letter of intent is often the closest thing a startup could achieve towards validating product-market fit. Therefore, LOI's are often expected by investors prior to investing when a startup has no paying customers yet.

Method

A Letter of Intent (LOI) was created in order to validate interest of potential customers in SeeFood. Rather than asking restaurants whether they would be interested in SeeFood, as was already done in chapter 3.3, the goal is to ask for commitment with the LOI. This reducing the chance of bad data. People might say they are interested because they do not want to be rude, but they are far less likely to show commitment for this same reason.

In the LOI there are 4 ways in which the customer can show their commitment for SeeFood:

Data

This is the lowest type of commitment you can get. Are they willing to give up (personal) data in order to learn more about the product? In the LOI this is done by asking for their email when expressing interest in SeeFood.

Time

People's time is often worth more to them than their basic data like email. In the LOI the customer is offered an opportunity to participate in a 30 to 60 minute interview to help improve the product.

Space

Another option for the customer is to express interest in a free pilot in return for their collaboration and feedback. Offering both their time (to give feedback on the pilot) as well as physical space by making (a part of) their restaurant available for pilot testing.

Money

Lastly, an option for the customer to express interest in paying for SeeFood once it is available is offered, giving multiple pricing options as defined in chapter 6.2.

The Letter of Intent also clearly states that signing it does not create a legal binding agreement between SeeFood and the signee. See the Letter of Intent below in figure 5.4, or in Appendix I.

SeeFood

Non-Binding Expression Of Interest

date ___ - ___ - ___

Hereby I declare that I am interested in
(*multiple options can be selected)*

- ❑ Receiving updates of the development of SeeFood by email.
  Email address: ______________________________
- ❑ Participating in an user interview which will take approximately 30-60 minutes, to discover what features of the product are most important.
- ❑ Participating in the pilot. This will help us validate and perfect the product, it will be free of charge in return for your collaboration and feedback.
- ❑ Being one of the launching customers and agreeing to subscribe to SeeFood for a period of at least 3 months.
  For the price:
  - ❑ Monthly 1% of total restaurant revenue per month.
    SeeFood app, automated 3D scanner and 1 tablet per 3 chairs provided
  - ❑ €150/month for automated 3D scanner & app + €15/month for every tablet
  - ❑ Other (please specify): ______________________

Name: ____________ Restaurant: ____________ Signature: ____________

This letter does not create a binding agreement between the restaurant and SeeFood.

Fig. 5.4: Letter of Intent

Results

Ten restaurant owners have been approached for this method, showing them the earliest prototype of SeeFood working on a smartphone. This prototype allowed the option of placing the 3D scan of a hamburger menu in augmented reality.

Restaurants within the city centre of Delft were approached. No further preselection was made on which types of restaurants to approach. Out of the 10 respondents, 4 of them signed the LOI. Restaurant owners that were not interested at all in the SeeFood demo were not asked to complete the LOI, as they already cut off the conversation before being able to tell them what the LOI is.

Out of the 4 responses, all 4 were willing to give up their data (email address) to stay up-to-date about SeeFood. 3 of them even offered their time to help, and cooperation if a pilot test were to be held at their restaurant. All three owners offered this even before being told about the LOI.

Lastly, only one owner indicated a willingness to pay for SeeFood. But compared to the total amount of restaurant, 10% of them willing to pay would already be very high. The same goes for the 30% that indicated they wanted to offer their time and space to help develop SeeFood.

Discussion

More respondents would have been needed to draw clearer conclusions from the LOI method. However, restaurant owners are difficult to get a hold of, as they are always busy. In many restaurants no owner was present, and staff suggested to send an email. But, as was previously discovered, with sending cold emails for interview request restaurants often just dont respond.

It is also worth considering whether this method would be more valuable to perform at a later stage. During this test, the full promise of what could be achieved with SeeFood was likely still unclear to restaurant owners. While this method did provide validation that there are indeed interested restaurants, the most important validation of getting paid customers was not achieved.

06

STRATEGIZE

In this chapter

Knowing the market, the customer, and how to make the product, a strategy around the product can be set, looking to find a viable business model.

Another look has been taken at the target market, narrowing down the scope of what restaurants and customers the focus should be on.

The marketing strategy is discussed. Defining what the product is, the pricing strategy, how to promote it, and the place where it will be sold.

Lastly, a future scenario is given. Discussing what direction should be the future focus.

6.1 Target Market

Geographical Focus

Initially The Netherlands was simply assumed as the target market, after having learning about other markets throughout the project, is this still the case? A brief look has therefore been taken at some other geographical markets, the US and Japan, and how they compare to the Dutch market.

United States

The United States is interesting because of its huge size. European startups sometimes decide to switch to this market, as scaling is easier in the US.

The cultural approach to dining out is a lot different though in the US. Where in The Netherlands it can be seen as more of a relaxed experience, the US is focussed on efficiency. This would allow for the more efficient ordering aspects of SeeFood to likely be more successful in that market, but tabletop tablet companies like Presto or Ziosk might already be too big to compete with.

Also, in the US market the prevalence of by far the most established competitor, Kabaq, would make this market dangerous. As Kabaq has a few years of experience and a fully developed app and scanning pipeline, there is little competitive advantage SeeFood would still have. European and Dutch competitors are all still at somewhat the same stage of developing an AR menu, making it a lot easier to compete with them for market share.

Japan

Japan is the only country where the physical counterpart of SeeFood, sampuru (fake food), has been very popular. This might make Japan, which is also one of the most advanced countries in terms of technology (Delta2020, 2018), potentially an interesting market for such a concept.

Japan, used to have an unhealthy startup environment due to a culture of very low risk tolerance, but this is starting to change (Choudhury, 2018).

All this makes Japan initially look promising for the idea of SeeFood. But it is possible that there might be unknown cultural reasons why SeeFood might not be a success there.

The Netherlands

The Netherlands is the current market SeeFood is located in. Staying in this market gives the benefit of no cost of startup relocation. Also, already having gained knowledge about this market, having contacts in the market, and no strong need to switch to a different market, staying in The Netherlands would still be the best option.

As was learned from talking to restaurants, the Dutch restaurant industry is a very 'local' thing. Making it easier as a local to gain the trust of restaurant owners and convincing them to give SeeFood a try. It is assumed that some foreign markets might have the same attitude towards international startups. Making it harder to succeed there.

According to the Hofstede's cultural dimensions theory, The Netherlands has a medium-high risk tolerance (Nomadlist, 2018), therefore making it an OK (but not the best) market to be in as a startup.

While Japan looks promising, pivoting the target market to there is likely not the best decision right now. As Japan has a very different culture compared to The Netherlands and a huge language barrier as not everyone speaks English. These two aspects are likely not to change anytime soon, therefore making Japan rather only interesting as a potential expansion market. Where there would need to be a local team of Japanese to do the business there.

Market characteristics

Based on learnings throughout this project, the market can be defined narrower now.

The initial geographical focus can even be further limited to the Randstad within The Netherlands, as there are likely enough restaurants that would be interested and it is beneficial to be close to your first customers in case on-site maintenance is needed.

Since the main benefit would be savings on staff, bigger restaurants are more easily able to reduce their staff. A 10% staff reduction when working with 10 people would allow the restaurant to work with 9 people. While a restaurant with less people on staff will still need the same headcount with a 10% reduction. Effectively eliminating most potential cost savings.

Budget wise it is best to focus on low to mid-end restaurants, as high-end restaurants turned out to be hesitant about cutting staff.

In order for pictures or 3D models of food to provide added benefit, the restaurant needs visually good-looking meals. Restaurants that have this will have the most gain from SeeFood.

Addressable market

Knowing a bit more about what target market to focus on and what market characteristics are important it is possible to more narrowly define the size of the market; what is the addressable market?

As previously determined, the worldwide restaurant market is around 15 million (Balcan, 2014), this would be called the total addressable market (TAM).

Deciding to focus geographically on The Netherlands limits the service addressable market (SAM) to all the 14.000 restaurants in The Netherlands.

Filtering on region, size, budget and taking the percentage of currently interested restaurants would leave around 280 restaurants (rough estimation) that would be in the service obtainable market (SOM).

Lastly, the Launch Addressable Market (LAM) (Parker, 2015) looks at the number of restaurants that would already be enthusiastic enough to pay for the product during the minimum viable product (MVP) phase. This last group is the most interesting to target at the moment, as they would be the first paying customers. But finding these restaurants might be difficult, as there likely will only be very few of them. Given the previous data from the letter of intent method that 10% showed an interest to pay for SeeFood, this would likely be your LAM. Given the small sample size of the letter of intent testing, a more conservative estimate of LAM being 5% of your SOM has been made.

CHARACTERISTICS

Region	Randstad (NL)
Size	60+ seats
Budget	Low- to mid-end
Meals	Look visually good

ADDRESSABLE MARKET

TAM	15.000.000 restaurants
SAM	14.000 restaurants
SOM	280 restaurants
LAM	14 restaurants

6.2 Marketing Strategy

Positioning SeeFood within the market is done using McCarthy's 4 Ps marketing mix model. Defining what the product is, the pricing strategy, how to promote it, and the place where it will be sold.

Product

SeeFood is provided as a product service combination to restaurants. SeeFood is an augmented reality menu for restaurants that helps their visitors make a better choice in what they want to eat. Visitors will be able to browse the menu on a tablet and see 3D models of each meal projected in 1:1 scale on their table in augmented reality.

Restaurants will be given a choice if they want to make the app available directly to their customers, or if they want to lease tablets that can be given to visitors as menus. Depending on occupancy restaurants are advised to use 1 menu per 1-4 people.

The option for tablets is strongly advised in the begin, as it would ensure a proper user experience for people using the app, because the development will be targeted on optimizing the experience for this tablet device. Later on (in 1-3 years) a definitive switch will be made from tablet menus to online digital menus available on people's own devices, but this is not feasible now as few customers would have phones that support augmented reality. The concept of digital menus on people's own devices will eventually bring scalability and bring the cost down for restaurant owners. Since the cost (of tablets) was one of the main reasons why some restaurants do not want SeeFood.

Scanner

In order for restaurants to be able to quickly scan new dishes whenever they want, a fully automated 3D scanner is provided to them. The chef can place the meal inside the scanner, press the button and within 1 minute the whole dish will be photographed and the photos send to the cloud for further processing. The restaurant will receive the processed model 30 minutes after scanning.

Menu app

Each restaurant will get their own branded version of the SeeFood app. The app comes with the basic functionality to view the 3D models of the meals in augmented reality, and browse through everything on the menu. The app is optimized for usage on tablets that the restaurant can optionally lease, but it will also work on most new consumer smartphones. However, restaurants would then be limiting who can use the menu app, as not everyone will have a recent smartphone that can do AR.

Fig. 6.1: The scanner prototype that was developed

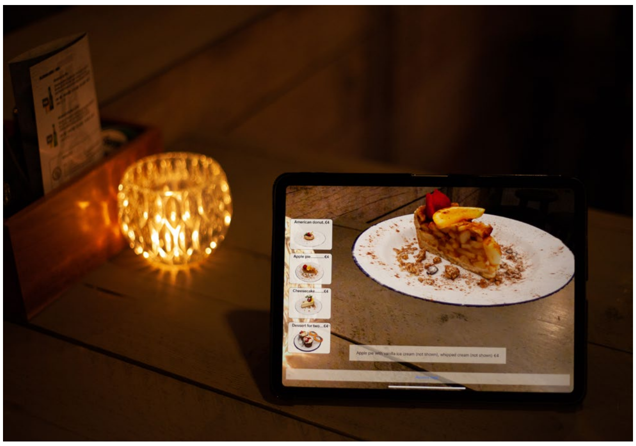


Fig. 6.2: The SeeFood AR menu app prototype that was developed

App Features

The menu app will over time gain new features. Based on the exploration of the market and the interviews with visitors and restaurants, the most important features that the app should get in the future were defined. These 9 features were ranked in terms of importance, with number 1 (order in the app) being the most important. This ranking presents the order in which the features will need to be developed and added to the menu app.

1

Order in the App

Guests will be able to send their orders directly to the kitchen from the menu app

2

QR-Codes

A QR-code will be placed on every table, that links to the (web)app of SeeFood

3

POS System

All tablets will become a POS system so that consumers can pay without the need for staff

4

Customer Analytics

Restaurants can gain insights into their customers' behavioural patterns within the menu app

5

Personalised Accounts

Guests will be able to create a SeeFood accounts which will remember their preferences

6

Social Sharing

Guests will be able to share the 3D models of what they've ordered on their social media

7

Website integration

Restaurants can display the whole menu with interactive 3D models on their own website

8

Reservations

Guests will be able to make reservations on the restaurant website without commission

9

Inventory Management

Restaurants will be able to keep track of their stock based on what is ordered through the app

Price

Setting a price can be difficult as a startup. The traditional pricing models do not work, as there often is not an established market or a competitor with a validated price point (Sequoia, n.d.).
Still the AR menu competitors have been analysed for their pricing strategy. While now removed from their website, the Dutch competitor FoodStory set their initial pricing at €75 per dish scanning fee, combined with a monthly licensing fee of €99 for a restaurant to be in their app. US competitor Kabaq also does not mention pricing on their website, but at some point when they had 15 customers they would charge each restaurant between $150 and $199 per month (Rao, 2017).

A subscription pricing model like the competition has chosen seems like the best option. As a subscription model will generate a steady and predictable income as a startup. This makes it possible to keep improving the service and adding new features.
Based on a cost estimation developed as part of a financial model (see Appendix F), a monthly subscription fee of €150 per month was defined. This would include both the lease of the 3D scanner and a license to use the SeeFood app.
Different from FoodStory's pricing, the models that are scanned with this automated 3D scanner will be free.
An initial one-time setup fee of €200 will be asked of restaurants. This fee serves as an assurance that the restaurant is serious about using SeeFood, thus lowering the risk of customers cancelling the product in the first few months. As it will take a few months before the costs of customer acquisition and the time spent helping the customer getting started are earned back.
Lastly, restaurants have the option to lease the amount of tablets they wish to use in their restaurant for the menu for the price of €15 per tablet per month. But they would also be free not to get tablets and make their visitors use it on their own phones if they have a compatible smartphone.

Two different pricing models have been considered, based on different pricing preferences by restaurant owners. Next to the fixed monthly subscription fee, one restaurant suggested using commission based pricing. This would make the success they achieve with SeeFood be reflected in the price they pay for it. For this model the pricing became again a €200 one-time fee, but in addition a fee of 1% of the restaurant's revenue each month. The commission based pricing would for this price include 1 tablet per every 3 seats in the restaurants. Validating both these pricing models through the Letter of Intent method (see chapter 5.2), many other restaurants found 1% too much and would prefer a fixed subscription fee.

SUBSCRIPTION PRICE

One-time Setup Fee	Subscription Fee	Tablet Lease
€200	€150/m	€15/m*
To scan the initial menu and explain how the product works	Includes the lease of the 3D scanner and the license to use the SeeFood app	We provide a fully configured iPad you can use right away
		* Per tablet

Promotion

To bring SeeFood (at a later stage) under the attention of all Dutch restaurants, a promotional strategy will be needed. From interviews was learned that restaurant owners stay updated on the newest food services innovations through trade fairs and sometimes trade journals.

The most important companies in these field have been defined: the biggest trade journal, the biggest branch organisation, and the biggest food services trade fair. When promotion is needed in the future, these companies should be the first options to consider.

Fig. 6.3: An article in Misset Horeca's trade journal

Misset Horeca

This is the largest trade journal in the Dutch food services industry. Misset Horeca reaches nearly all of the restaurants in The Netherlands with their journal.

Koninklijke Horeca Nederland

Koninklijke Horeca Nederland is the largest branch organisation for the Dutch food services industry. It might be interesting to place the product with a small discount on their platform.

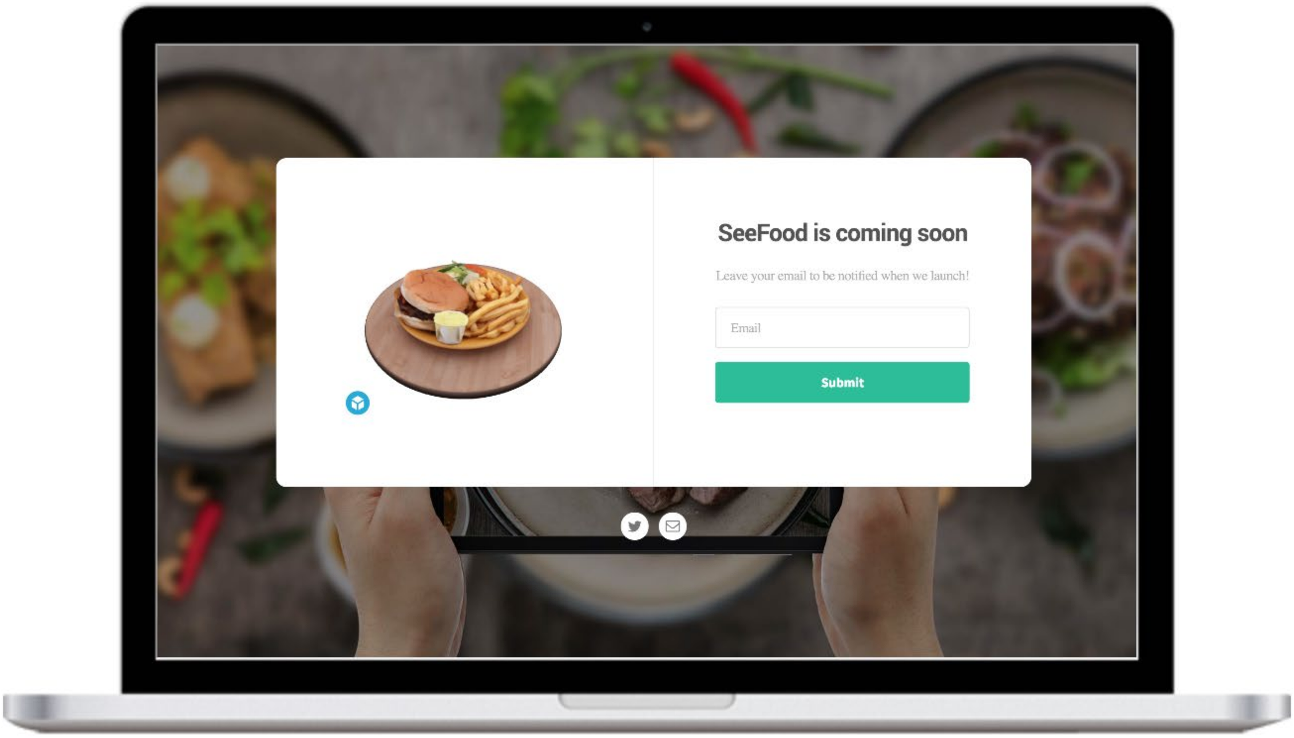
Horecava

Horecava is the largest trade fair in the Dutch food services industry. It is held annually, and with thousands of visitors this is the place to be. They also award food services innovations awards every year, which could give lots of free publicity if you were to win.

Place

Of the 4 Ps, place is likely the least important when developing a B2B2C product. As there is no physical retail location of the product. The only place where the product will be available and 'for sale' would be on a website.

An initial landing page was made to briefly show some aspects of the project to potential customers or other interested parties. The domain www.seefood.app was bought and used to setup this landing page.
The site currently shows one of the scanned 3D models, which can be viewed interactively in the browser. So visitors will be able to fully rotate the model and zoom in and out. A newsletter subscription field was also added to collect email addresses of people or companies who might be interested.
This landing page was a quick solution to have something up online, and to claim the domain name before someone else would have bought it. In the future, this landing page will be turned into a sales page. Detailing all the aspects of SeeFood and allowing interested restaurants to get in contact and schedule an introductory meeting.



“A 'startup' is a company that is confused about
1. what its product is
2. who its customers are
3. how to make money.”

- Dave McClure, 500 startups

6.3 Future Scenario

Main Strategy

To define what the main product strategy should be, first a future vision for SeeFood was defined, together with a mission statement and an ambition. These statements can be read on the next page.

From the ambition of becoming a market leader in the Dutch restaurant menu business, the main future strategy is therefore on a scalable mobile (web)app restaurant visitors can use. By scanning a QR-code on a table the user will be taken to the website or app and be shown the AR menu on their own phone. With a custom QR-code at each table, the exact location of the visitor is known. Making it possible for them to place orders directly to the kitchen, and runners in the restaurant will know where and to who to deliver the order.

Fig. 6.4: SmartBox by Zappit, a QR code takes users to a loyalty website

Having a webapp, rather than a traditional app, would eliminate the need for the user to download and install an app on their phone. Something most people do not like to do. While webapps currently do not support the AR frameworks necessary for SeeFood to work, it can be expected that within a few years these will be available, as all major technology companies are now investing lots of money in their mobile AR frameworks.

Restaurants will also be advised to have a few tablets as backup if people still want a menu but cannot use their own phone.

Partnerships

Rather than achieving the ambition just as SeeFood, other companies might be able to help achieve this through a strategic partnership. Throughout the project some companies were defined as interesting potential partners for the future, but no agreements have been made yet with any other party as of now. All the potential partnerships can therefore be found in Appendix J.

Alternative Strategy

An alternative (or additional) future strategy would be to position SeeFood as a temporary marketing tool for restaurants. From the interviews with restaurant owners, many already envisioned the possibilities of word of mouth marketing that SeeFood might trigger. But this effect could become the main approach with this strategy where, rather than replacing the menu, SeeFood will only be an addition to the menu. In this scenario, instead of an indefinite subscription, restaurants would opt to buy SeeFood as a marketing tool for a fixed period of time (e.g. 3 months).

Financial Predictions

A financial model was created to predict how the company might evolve over the next 5 years to become profitable. As this model has been made earlier within the project, it focuses solely on leasing tablets to restaurants, and does not account for the future strategy of going for an app users can install on their own devices.
The model leans on a lot of assumptions about the market share that can be captured and all the costs related to developing SeeFood and running the company. Therefore, significant conclusions cannot be drawn from this financial model at this moment, as the error margin is too high. The model was not completely useless, as developing the financial model did help create a picture of what financial aspects might be important in the future. The model and the limited conclusions can be found in Appendix F.

Future Vision

Developing this idea as a business, there is a need for a vision, mission and ambition statement about what the company aims to achieve.
The vision is what the company believes will be the future, the mission describes what the company wants to be, and the ambition is what the company hopes to achieve within the near future (2-4 years).

VISION

The boundaries between real and virtual will blur, making life a seamless blend.

With the ever-increasing developments in machine learning, augmented reality and computing power, parts of the digital world will become indistinguishable from the real world for the human eye. We believe this will become the new norm, with these ‘fake’ objects around us becoming accepted by society as a part of the world and being considered ‘real’.

MISSION

Transform the way people decide their food choices, supporting them to make the best choice in every situation.

Food plays a major aspect in everyone’s life, it influences both physical and mental health. However, people often do not know precisely how a certain food influences these factors, and might impulsively make food decisions that have bad long-term effects. We believe that with the use of nutritional data and quantified-self data it is possible to predict the short- and long-term effects of a certain food on a person’s health. By presenting someone with these predictions at the right moment (e.g. during grocery shopping) it would aid them in making a well-considered decision, resulting in a happier and healthier life.

AMBITION

SeeFood will be market leader in the Dutch restaurant menu business by 2020.

The menu business is often a small side business of big restaurant services companies or printing companies, with very few companies with the sole ambition of creating restaurant menus and innovating in this space. We believe the menu business deserves its own dedicated industry and we strive to become market leader of this new industry.

07

CONCLUDE

In this chapter

Concluding on the whole project, discussing what could have been done better and defining future steps when continuing with this project. Answering the final question, can this project be a viable startup?

7.1 Conclusion

Reflecting back on the initial design brief, a few questions were proposed that should be answered within this graduation project. Coming to a conclusion, these questions can now be answered.

What is possible within the realm of augmented reality, and how can appetizing 3D food models be created?

Having analysed the augmented reality market, a lot can be done using augmented reality. The use cases are varied, as the technology gives a canvas to overlay digital information on the real world. It should be noted that the technology is still in its infancy. What is possible with AR nowadays is more for fun and gimmicky applications. But the technology will evolve, likely very rapidly as all major tech companies seem to be betting big on their augmented reality platforms.

The creation of appetizing 3D models was achieved through learning a photogrammetry workflow, and iterating on this. Each time learning better and better what factors influence the scan results and how to optimise for this.

This project should validate if these assumed problems are important to customers and to restaurant owners; do they want the product?

This hypothesis turned out to be both true and false. As it varied greatly per person what their opinion on it was. Some restaurants really liked the idea of SeeFood, and even indicated an interest to pay for the product. While other restaurants did not want to have anything to do with a digital menu.

For restaurant visitors the results were similar. Some people were very enthusiastic about it, especially people that currently already experience problems with a menu, such as vegetarians. There was also a big group was quite indifferent towards the product. They would not mind using it, and would still enjoy it a bit more than a regular menu, but they would not choose one restaurant over another because of having a SeeFood menu.

The addition of augmented reality should also be considered: Do customers want this, and is it feasible to bring this to market?

Initially, potential users were hesitant about augmented reality, claiming not to see any value in it. But when shown later demos of SeeFood, nearly everybody liked the effect augmented reality had. However, again only a small group was super enthusiastic about being able to use augmented reality.

Regarding the feasibility, this project is likely two to three years too early. Augmented reality is still something for early adopters at this moment; people who have the newest smartphones and are also aware of the AR capabilities of those devices. But sooner or later, users will upgrade their phones and augmented reality will be readily available for most people.

So for now, developing something for AR could be deemed undesirable, as you will likely only reach a small target audience. But this shift towards mass market is likely to happen in a few years. Rather than waiting for this to happen and risk being late, now might already be the right time to get into AR development.

Can this project be a viable startup?

Yes! But more experimenting towards finding product market fit definitely needs to be done. As reactions so far have been mixed between super enthusiastic, indifferent or even rejecting. The reasonable amount of very enthusiastic reactions proves there is some market need for a product like SeeFood. The overall mixed reactions however signal that this product likely is not fit for general usage, at least for now. Therefore, the specific niche within the restaurant market that is super interested in SeeFood needs to be found. Or a pivot to a slightly different product would also be a possibility, the options for this are further discussed in chapter 7.3.

7.2 Discussion

What were in hindsight the things that went wrong during this project, and ideally should have been tackled differently. Next to that, also giving some recommendations of what aspects of the project would be interesting for further research.

A pitfall within this project was the broad scope of the project, as the envisioned product that was to be designed basically consisted out of 3 separate products: a menu app, a turntable based scanner, and a photogrammetry workflow to create 3D models.
Next to that, the product also had 2 stakeholder: the restaurant visitor and the restaurant owner. Both parties had to be heard what their opinion on the concept was. Again making the project a lot broader.
On top of that, the project was executed as a self initiated entrepreneurial project with the aim of starting a startup. So there was no existing company knowledge, no clear vision upfront, and a strong need for the outcome to be successful so that the project could be continued as a startup.
All these factors together made for an incredibly broad and difficult project. The fact that so many different things had to be done lead to a lack of depth for most tasks. Reflecting back on this, the project scope should have been a lot more narrowed down, focussing on perfecting one part of the project, for example building and optimizing the 3D scanner.
Ideally this project would have then been combined with another student's graduation, so that the total work could have been split into two different projects.
Choosing a more narrow scope might have killed the startup aspect of this project though. As in order to create a successful startup out of this project, the whole context should be analysed; knowing where the opportunities in the market are and on what the startup should focus.

More user and customer validation should also have happened. Again, due to the wide scope of the projects, four different user studies (interviewing users, interviewing restaurant owners, pilot and letter of intent) were conducted. This broad approach of doing too many things, combined with difficulty finding people willing to participate in the different user studies, lead to a low sample size for each of the user studies. Making the conclusions from these studies less significant.
Future studies are recommended to discover the effect of 3D food models on people. As there are already some scientific studies on the effect food pictures can have, but none so far have been conducted using 3D food models.

Regarding the 3D scanning analysis, more scanning techniques should ideally have been compared. Now, the different scanners and techniques were only compared on paper, but that comparison does not account enough for the context of scanning food items.
A comparison between the Artec Eva white light scanner and photogrammetry was done, where the very expensive Artec Eva gave significantly worse visual results. This result can still be debatable, as learning how white light scanning works this technique should in theory be able to give similar visual results to a photogrammetry process.

7.3 Continuation

With this thesis being wrapped up, the decision whether and how to continue with this project needs to be made. Evaluating where the opportunities are lying, and what things would need to happen for this project to turn into a startup.

While there is not one golden opportunity to pursue at this moment, the broad scope of the project did reveal multiple directions in which to possibly continue this project.
The most interesting opportunity to pursue would be mobile ordering at restaurant. As this market is now starting to take off, and there are no established players yet in The Netherlands.
Another big opportunity is the creation of a cheap automated 3D photogrammetry scanner. During this project only a semi-automated scanner was developed, as full automation would have taken a lot longer to develop. But it is conceivable that this automation could be achieved, and even be done with cheap raspberry pi cameras. As there are no low-cost fully automated photogrammetry scanners on the market, developing such a machine could make for a good business case. As the applications of such a scanner would go way beyond just scanning meals for restaurants.

Staying closer to the core idea of 3D food models, the home delivery market and catering services market that were briefly explored could both still be interesting opportunities. More research into these markets would be needed to determine whether they are worth pursuing.

Team
SeeFood is a complex product with lots of disciplines needed to make it a success. Creating a founding team of around 3-4 people from different disciplines will likely be very beneficial to success. As this project was, and still is, too big to make it a success alone.
The most needed disciplines right now would be industrial design, computer science and mechanical engineering. As respectively customer research, menu app development, and scanner development are most needed at this stage.

Funding
To make continuing as a startup feasible, funding options should be considered. As it likely could take months or years before the startup would reach profitability.
A small investment was already received in the form of the TU Delft Startup Voucher. This investment helped to make it possible to purchase the materials needed to create the prototype used in this project.

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Thank You
Dorus van den Oord