Design of a 3D Head-scanner.

Facilitating the design of ultra-personalized products for the differently-abled.

Yaman Kalyan Gupta
Integrated Product Design
M.Sc. Graduation Thesis

TU Delft

M!

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Facilitating the design of ultra-personalized products for the differently-abled.

MSc. Graduation Thesis
August, 2021

Yaman Kalyan Gupta
Integrated Product Design
Faculty of Industrial Design Engineering
Delft University of Technology

Chair: **Dr. Yu Song**
Department: Mechatronic Design

Mentor: **Laura Ahsmann**
Department: Fieldlab UPPS

Company: Maatbril
Company Mentor: **Jan Berend Zweerts**

Appendix A

A.1. Project Brief Document

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Gupta

initials: Y.K. given name: Yaman Kalyan

student number: 5084695

street & no.:

zipcode & city:

country:

phone:

email:

Your master programme (only select the options that apply to you):

IDE master(s): (★) IPD ( ) DfI ( ) SPD

2nd non-IDE master:

individual programme: - - (give date of approval)

honours programme: ( ) Honours Programme Master

specialisation / annotation: ( ) Medisign

( ) Tech. in Sustainable Design

( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Yu Song dept. / section:

** mentor: Laura Ahsmann dept. / section:

2nd mentor: Jan Berend Zweerts

organisation: Made4Eyes BV / Maatbril

city: Amsterdam country: The Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Design of a 3D Headscanner for children and adults with pathologies — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 03 - 03 - 2021 — 27 - 07 - 2021 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The design project is being organized by the MedTech start-up company Maat! which specializes in creating customized eyewear for children and adults with special pathology such as Down syndrome etc. For this purpose, the company makes use of 3D printing and 3D Scanning technologies to ensure a proper fit for each and every individual.

The parties involved in this project are primarily the client company Maatbril who is looking for a faster 3D scan technology using inexpensive scanning solutions to address certain end-client limitations, e.g. the observed inability to sit still. Secondly, the graduate in TU Delft is also one of the stakeholders since he will be responsible for the design of the final product, both from a technological and a design perspective. His intention is to cater to the client's needs and also some of their wishes and for that reason, they will stay in close contact with the clients throughout the project. The next stakeholders are the end-participants who are the users of the scanner, and they are more interested in the personalized eyeglasses, which is designed based on data acquired from this scanner and has a tailed fit of their needs. It is worth mentioning however, that the aesthetic design of the scanner could influence their interaction with the product and therefore is an important point of consideration. Lastly, there are the operators who are tasked with ensuring that the scanner works correctly and that the ideal working conditions are met while preventing discomfort for the end participant.

Currently, the main opportunities are making use of the client's closeness to the end-user to carry out interviews and understand the stakeholders which could help accelerate the project and improve the end result significantly. Secondly, the TU Delft's experience on developing 3D scanners in similar projects provides a number of precedents to build up on and access to facilities/resources that would help to ideate, iterate and test in a number of scenarios thus creating a relatively complete product prototype.

There are also certain limitations in this project, the biggest threat is the limited accessibility to the end-participant or a scanning session due to the COVID pandemic. A possible way to circumvent this limitation is to ask the client for materials and recordings of previous similar sessions which could serve as a proxy method for a better understanding of the process. Secondly, the difficulties of validating the prototype with end-users at the validation phase of the project can also be foreseen, though some aspects of the scanner, e.g. the aesthetic of the new product can be partially validated by remote sessions. Another very important limitation is the client's cost-price limitation which is about 500 euro.

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APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Yu Song date - - signature

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: ______ EC

Of which, taking the conditional requirements into account, can be part of the exam programme ______ EC

List of electives obtained before the third semester without approval of the BoE

YES all 1st year master courses passed

NO missing 1st year master courses are:

name date - - signature

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name date - - signature

introduction (continued): space for images

TO PLACE YOUR IMAGE IN THIS AREA:
- SAVE THIS DOCUMENT TO YOUR COMPUTER AND OPEN IT IN ADOBE READER
- CLICK AREA TO PLACE IMAGE / FIGURE

PLEASE NOTE:
- IMAGE WILL SCALE TO FIT AUTOMATICALLY
- NATIVE IMAGE RATIO IS 16:10
- IF YOU EXPERIENCE PROBLEMS IN UPLOADING, COVERT IMAGE TO PDF AND TRY AGAIN

image / figure 1:

TO PLACE YOUR IMAGE IN THIS AREA:
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- NATIVE IMAGE RATIO IS 16:10
- IF YOU EXPERIENCE PROBLEMS IN UPLOADING, COVERT IMAGE TO PDF AND TRY AGAIN

image / figure 2:

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The biggest challenge associated with this project is that current scanners employed by the clients are slow as the scanning duration is approximately 15 seconds. During this period, the participants are expected to stay still, which is difficult especially for this target group. For this purpose, a primary requirement of the new scanner is a faster scanning speed. The acquired 3D-scan should include both ears and the frontal part of the head, both in texture and mesh. The texture is imperative for finding landmarks by face recognition software. For instance, the texture of the regions where the temple tip bends downwards. Since the end-participants have might have unique anthropometric measures, accuracy in terms of body data acquisition is a very important requirement. Additionally, the product needs to adapt to the unique ergonomic setups of the users and should therefore be designed accordingly. Finally, because the product is also intended for children, the design needs to address their specific cognitive needs. A friendly, and medically safe design which provides them with a certain level of visual comfort but should also not be intrusive is essential for the acceptance of the design. Lastly, the portability of the product is also an important part of the design as the product will be taken to clients' homes for the scanning session.

Certain challenges and struggles foreseeable in this project are my limited knowledge on the new hardware and software required in this project. Tasks such as researching on the scanners, learning the software or getting guidance on them are certain steps that would have to be taken to overcome these. Further guidance can also be provided by the supervisors in the form of documents, papers that can speed up the process or support in building the electronics.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

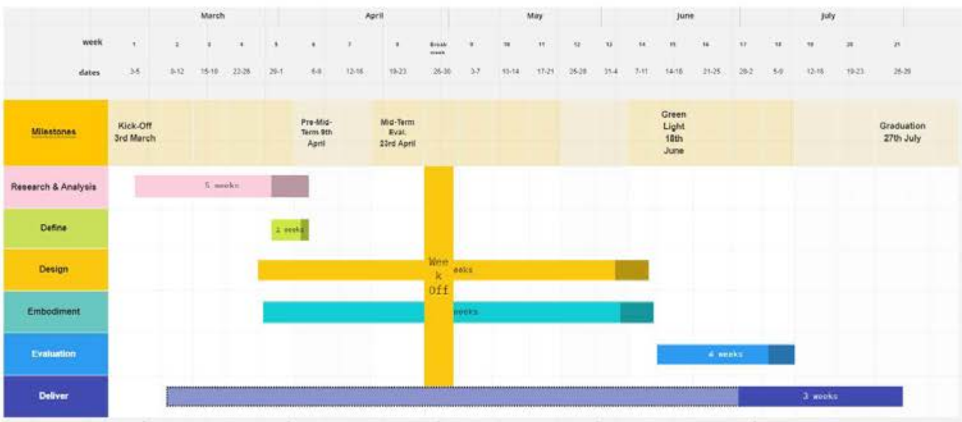
For this project, research areas include scanning technologies, shape modeling and research on the end user-group, research on their cognitive and physical needs, etc. After gaining a holistic idea and sufficient data on all these aspects, the intent is to test the technologies on speed, accuracy, feasibility to finalize hardware options and architecture that works best (within limitations). Some concept iteration would then help in the embodiment of a working prototype.

For this project, the intention is to design a physical product/system of products, known collectively as a 3D Head-scanner. The exact nature of the product/product system is still unknown and shall be conceptualized based on the scanning requirements, hardware limitations, the desired interactions and the requirements of the client and end-user. The 3D head scanner/system of scanners will consist mostly of hardware such as a system of cameras, sensors, etc. Thereafter, there will be a (software/hardware) system for synchronizing scanners and post-processing collected data. The final outcomes of the scanner be presented in the form of a 3D model to the retailer in order to design the eyewear around.
Bringing all this hardware systems together would require an in-depth study of product architectures and what works best for this scenario. In addition to this, a study and implementation of statistical shape modeling techniques might also be useful to process the scan data into a usable format for the client.
Since the end-participants are children, it is also important for the design to cater to their needs and show that in the design. Besides of the technical functions, the intention is to create an engaging and medically safe product to engage the users in a comfortable (and possibly playful) manner thereby letting the scanners function efficiently and minimize the potential risks regarding different activities in the useage.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 3 - 3 - 2021   27 - 7 - 2021 end date



Research & analysis	Define	Design	Embodiment	Evaluation	Deliver
Scanning Technologies, Available scanners, Advantages/Disadvantages, Compare and Conclude; Various pathological conditions, target audience, existing method of scanning, conclusion, field research with client.	Program of Requirements, Define Scope, Final Vision	Technical Explorations, Comparison of tech, Choice of Tech, Ideation, Surface/Virtual Modeling, Directions, Final Choice.	Basic Technological Prototype, Casing, Form Prototype, Testing for Accuracy and Comparison with similar options.	Finalize Model, Validation with Client(?)	Final Proposal to Mentor, Supervisor & Client, Report, Video & Prototype, Final Presentation.

My project is split into 6 phases arranged in a linear timeline manner for the purposes of representation in a Gantt chart. Further, my activities within the phases are outlined at the bottom.

Something to notice in the chart are the darker colours at the end of each bar which signify the buffer periods arranged in case of delays in arrangement or communication which might lead to extension of certain phases. The initial target is still the end of the brightly coloured section for each phase.

Additionally, a pre mid-term is intended 2 weeks prior to the actual mid term wherein the intention is to meet with the supervisory group and show some progress and preparation prior to the actual mid term.

After discussion with the mentor and supervisor, it was decided to take a Week off after the mid-terms for rest and relaxation, though the intention is also to work throughout the public holidays which I wish to count within the 100 days of my work.

In summary, if everything goes according to plan, then the final defense should take place on the 27th of July 2021.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

The Headscanner project was selected in order to exercise a number of competencies in a live project where I am the primary project owner. A majority of the competencies that I wish to prove revolve around the knowledge obtained in the M.Sc. programme, specifically the AED project where I learned to look at all phases of a design project in depth all the way to the final working prototype. Particularly, I want to exercise my prototyping skills since it's been some time since I had the opportunity to work hands-on on something.

One of my main aims in taking this project is to further expand on my technical knowledge, that is experimenting with new and upcoming technologies and implementing them into the product to create a complete working solution. I find that in design, I am currently very visual or form-centric in my user approach where technology or engineering implementation is the secondary, therefore by working on this project, I feel that I would be able to combine both in equal measure to make a holistic product experience. I find myself also very interested in 3D Scanning technology which could be something that becomes even more relevant in the future.

Secondly, I wish to expand on my research skills and how I can find relevant information and then implement it in the project. I feel this would help me become a more complete design engineer and might even open up further research avenues for me.

Thirdly, I am very interested in working with electronics to achieve different results in this project since I have dabbled there a bit in the past and feel that this is an important aspect that I should have a deeper understanding of.

Lastly, as is a prerequisite of this project, I also wish to master certain aspects of programming(Python) through this project. This along with the other aspects, I feel would complete a well-rounded skillset thereby helping me in the future.

FINAL COMMENTS

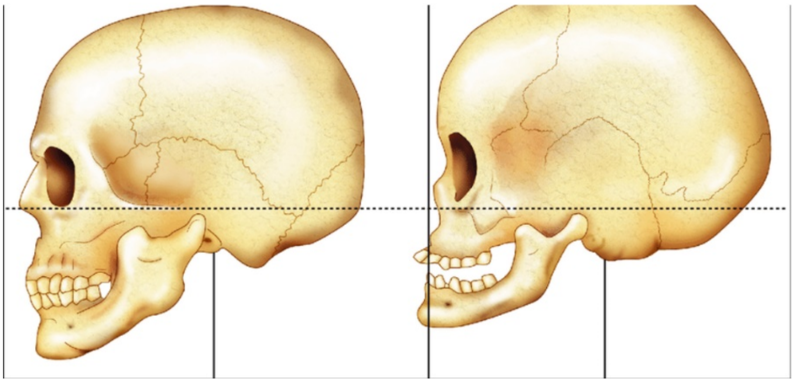
In case your project brief needs final comments, please add any information you think is relevant.

Appendix B

B.1. Target Users

B.1.1. Artec Eva (Structured Light)

The physical changes stemming from this condition mainly include flatness of the bridge of the nose and midfacial hypoplasia (condition where upper jaw, cheekbones and eye sockets have not grown as much as the rest of the face). Other minor abnormalities might also be present such as the shape of the ears, hands and feet. (Epstein, 1989)



In Down Syndrome, although the skull grows to nearly the same size as the normal adult, it presents *brachycephaly*, which means "short headed," and occurs when the right and left coronal sutures close prematurely. Brachycephaly results in an abnormally broad head with a high forehead. It is often associated with other craniofacial abnormalities. In Down Syndrome, the face is small, with underdeveloped maxillae, and the mandible is still relatively straight. (Benda, 1970)

It is worth mentioning, however, that not all people with Down Syndrome share the same physical characteristics, though they might appear similar on account of a few common recurring features. These features are as follows:

1. Epicanthic folds (extra skin of the inner eyelid giving the eye an almond shape (
2. Upslanting palpebral fissures (slanting eyes)

Other physical features include a single crease across the palms, short, stubby fingers, etc. They often tend to be short in stature with short limbs. (Fergus & Garbi, n.d.)

Young and early school age children with limitations in language and communication skills and cognition may present with increased vulnerabilities in terms of

1. Disruptive, impulsive, inattentive, hyperactive and oppositional behavior (raising concerns of ADHD)
2. Anxious, inflexible behaviors

3. Chronic sleep difficulties, daytime sleepiness, fatigue and mood related problems.

In a similar fashion, people of different age groups might experience vulnerability to different conditions stemming from their ability to communicate and cognitive skills.

In direct contrast, many children and adults show a wonderful disposition, they are fun-loving, interact quite well, make jokes or indulge in outbursts which may also lead to intrusive, uninhibited social behavior. (Munir. n.d.) Mental Health Issues & Down Syndrome - NDSS

Key hallmarks of Goldenhar syndrome are external ear anomalies and facial underdevelopment. The condition is mostly unilateral in occurrence with the right side more frequently affected than the left (left side considered a rare variant). It varies from other syndromes like Treacher-Collins syndrome in that unilateral facial involvement is seen leading to facial symmetry while TCS is bilateral. There are a number of corrective procedures for structural anomalies such as the ones for eyes and ears which can be corrected using plastic surgery. (Jangra, 2016)

Appendix C

C.1. Overview of Technology

To finalize a technology that is suitable for the head-scanner design, it was important to research existing surface scanning technologies currently being used in different industries, especially the body scanning sce6nario. Additionally, it was important to study their advantages, disadvantages and usage constraints in order to decide whether they would work in the envisioned setup.

It is important to mention that for the purpose of this project, only surface scanning technologies have been considered since the client only needs the outer contours of the client's face to design spectacles around. Within surface scanning, only the non-contact category is of interest keeping in mind the goal of the project which is to not agitate or make uncomfortable the person being scanned for which scanning from a distance is a viable direction.

Non-contact 3D acquisition types for body scanning generally include laser-based systems such as time-of-flight, laser triangulation, coded light systems or structured light, LIDAR, stereophotogrammetry, etc. These are further discussed in the sections below.

C.1.1. Structured Light

Structured light is basically a technique that works by means of a camera and a light projector wherein the light projector works by projecting a pattern onto the surface. The camera, which is located at a different position and orientation to the projector then captures the distortions in the pattern due to their varied depths on the organic surface (such as a human face) after which the system compares the shifted pattern position to the actual pattern position. Using triangulation (the relation between the projector, the pattern points and the camera), the depth values of each of the pattern points is determined by the camera which is finally used to create a depth map.

The Occipital Structure sensor Mark 2 is an example of a Structured Light scanner that works in tandem with an iPad making use of its RGB camera. Although highly accurate with an accuracy of 0.2%, the Structure Sensor costs 449/- making it one of the more expensive products that makes use of this technology.

C.1.2. Time of Flight

Time of Flight or ToF scanners make use of light pulses to create depth maps. They can be divided into direct Time of Flight or indirect Time of Flight where direct ToF makes use of pulses of light which are detected by sensors and indirect ToF makes use of phases of light. For the purpose of this research only the direct ToF was considered closer to the final requirement and therefore has been discussed.

Similar to Structured Light, direct ToF makes use of a projector to send a pulse of light at the subject. Since the speed of light is constant, the time taken by the sensors to sense the pulse of light is measured. Using this value and the speed of light, the total distance travelled by the pulse can be calculated. This value eventually helps to determine the distance between the object and the sensors. (Terabee, n.d.)

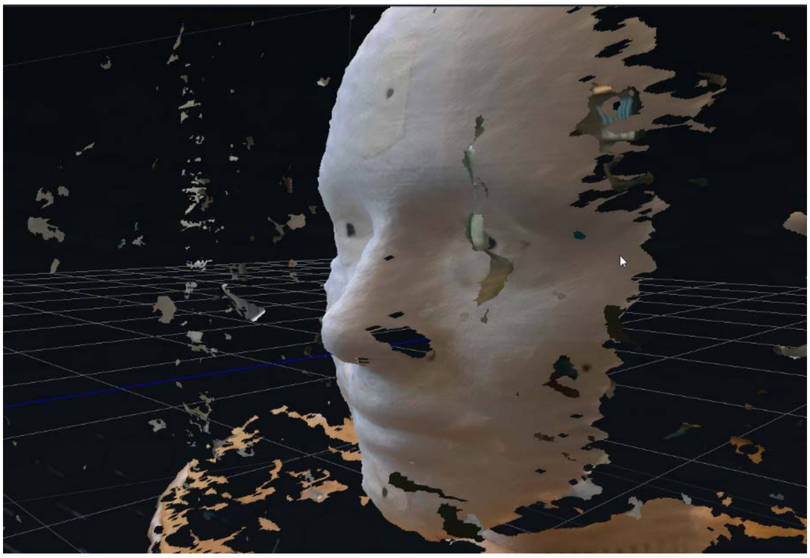
Further, there are more sub-types of ToF, i.e. LIDAR and ToF Cameras but both of which have not been discussed here due to their pricing which was deemed expensive on account of hardware setups or their accuracy which was considered out of range for the requirement. Additionally, LIDAR is considered to be an effective long-range scanner generally used to scan structures or environments which was not a requirement here.

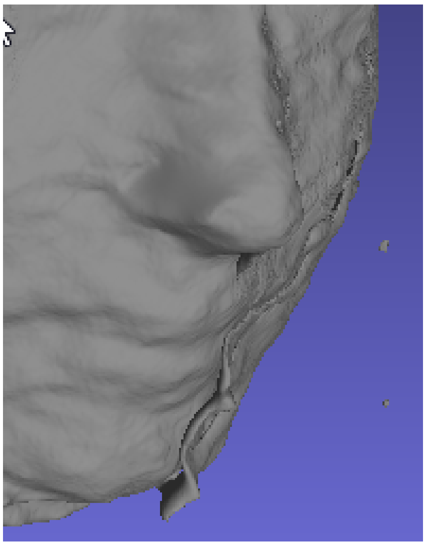
Further Study with D415

Once the D415 scanner was finalized, further test were carried out with the scanner to determine its performance with regards to various real world variables such as different sides of the head and the distance from the subject. For this purpose, two different tests were carried out which are described below.

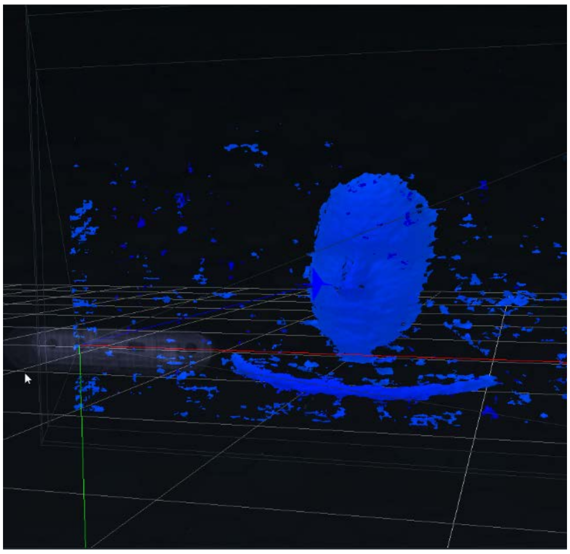
C.1.2.1. Disparity Changes according to plane of head

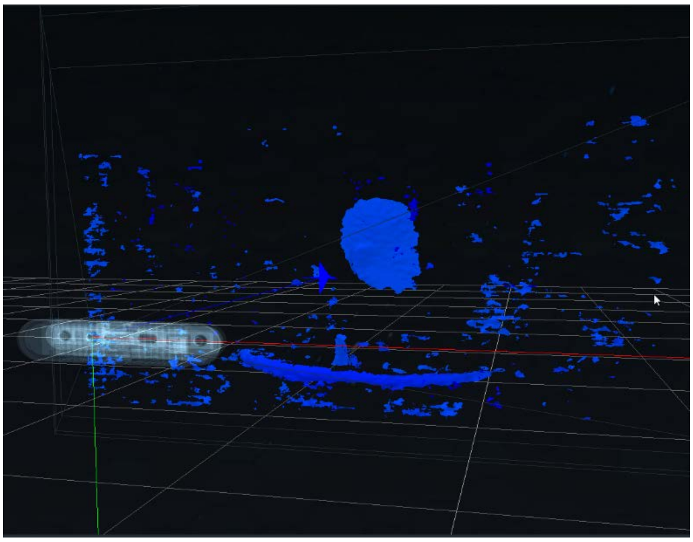
Disparity Shift was identified as a key element which affected the quality of scans considerably. However, the next experiment was to understand how much the disparity shift can be tweaked in order to only capture the desirable areas of the face without having more than the required overlap or capturing too little area. One other reason for this experiment was to ensure clean edges of the acquired surfaces. Having too little disparity, while capturing more of the visible head causes mesh tearing and a greater number of broken segments at the edges showing in the final acquisition which leads to greater cleanup times, excess data capture and undesirable edge flaring between multiple acquisitions when the final head is being aligned, the latter two of which can be seen from the **figure**. For this experiment, the setup remained unchanged.



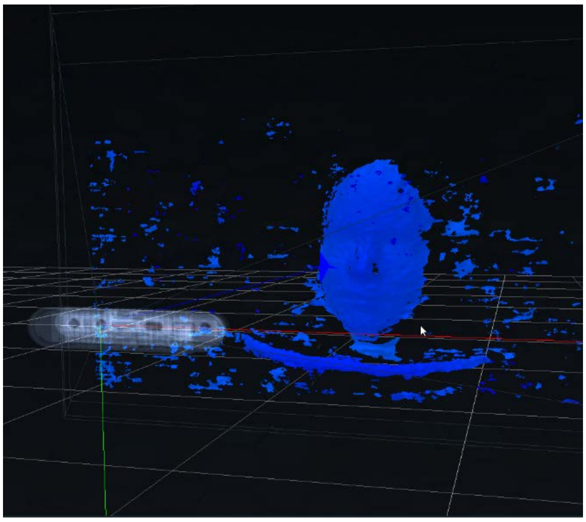


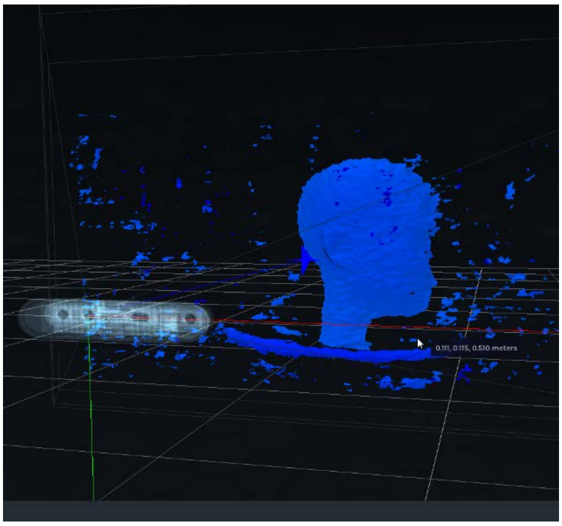
For the first test, the disparity shift value was kept at 103 with the scanners placed at a distance of 450mm from the head. The results obtained from the front of the head were similar to those obtained previously but the side of the head was seen to have too little capture to be be able to help in alignment. The results can be seen in **figure.**





Therefore, the disparity shift values were changed to 97 to increase the acquisition area and while a significant difference was not seen in the front of the head, a lot more of the side of the head was captured.



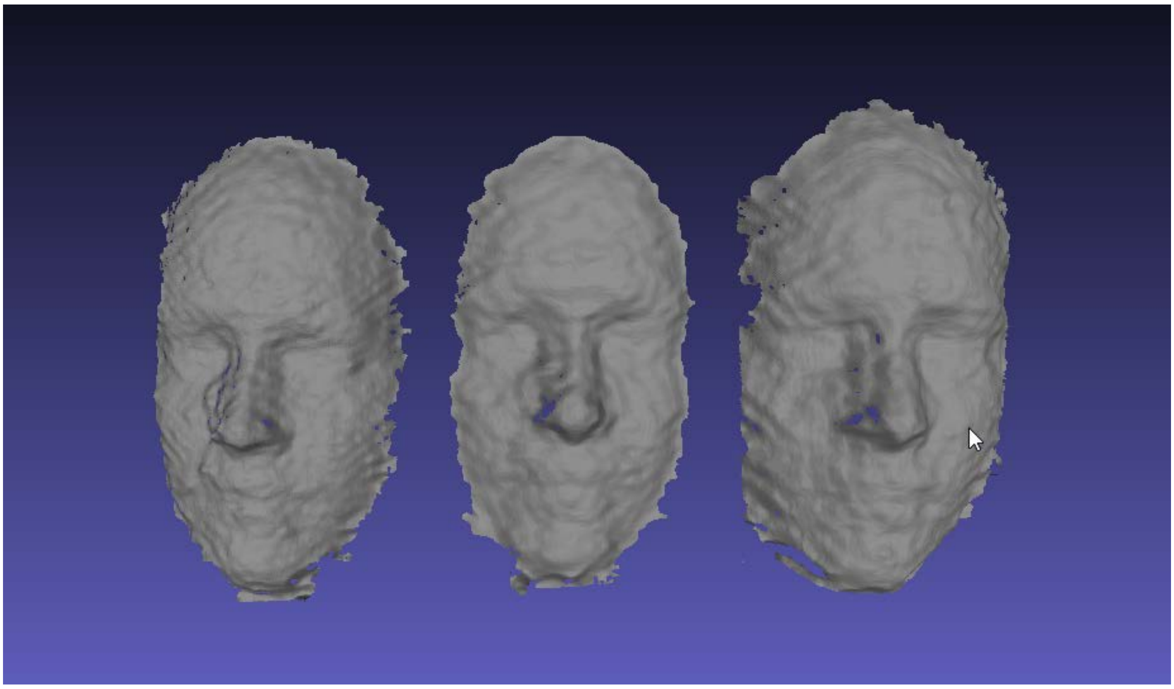


C.1.2.2. Distance and Detail capture

Once the disparity shift settings were tweaked according to the requirements, the next step was to test the ability to capture detail from different distances relative to the subject. For this purpose, no specific distance markers were set but rather ranges within which the scanner could be placed since in a real world scenario, placing the scanner at very specific distances from the subject could use up time and is also unnecessary since the results don't vary too much per 10 millimetres.

The selected distance ranges for this test were 350 to 400, 400 to 450 and 450 to 470 based on the study of proxemics in the previous sections. All distances were measured from the tip of the nose and anything beyond the given ranges was noticed to not capture anything due to the disparity shift values.

The difference in captured details is very minor, such as the elevation on the left of the nose(which is due to the landmark tape put there which is peeling off) and the . The elevation is clearest at 368mm distance which is the leftmost head but becomes less and less visible at 468mm which is the rightmost one. The head in the middle is placed at 450mm.



Appendix D

D.1. Market Study

D.1.1. Artec Eva (Structured Light)

The Artec Eva, pictured in Fig. 3b is a hand-held 3D scanner that makes use of structured light to acquire a 3D mesh of the target being scanned. It captures at a rate of 16 frames per second and has to be moved around the target by hand in order to capture the point cloud of the required area. One of the strengths of this scanner is its high 3D accuracy which is noted to be 0.1mm along with the ability to capture texture at 1.3 megapixels as well. It can function

in relatively dark environments using its white structured light to illuminate the subject thereby getting adequate texture data.

The procedure to operate this scanner involves a number of steps which are as follows:

- The operator connects two cables to the scanner, one to power it and the other to connect it to the system since it displays the captured mesh in real-time on the screen.
- Operator must then ensure that the target is within the bounding box being shown on the screen before they can flip the switch on the device starting to capture.
- Operator must keep their eye on the screen as they move around the subject while ensuring that target area to be scanned is being kept within the bounding box and at a constant distance from the scanner considering it has a minimum range.
- Once the concerned area is covered, operator then again flips the switch to shut off the acquisition automatically saving the acquired point cloud.
- Point cloud is then processed using a number of algorithms such as global registration, outlier removal etc. before it is ready to be imported in any format desirable.

From carrying out a number of scans using the Artec Eva in order to achieve a suitable benchmark, it was understood that there is a significant learning curve involved with operating this scanner.

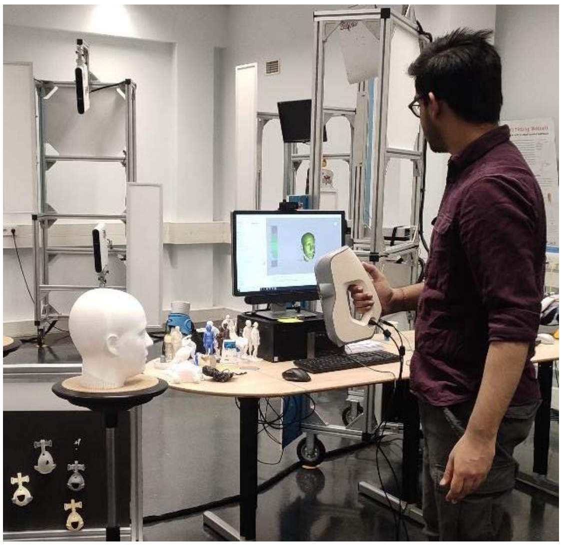


Fig. 3c: Scanning a white dummy head using the Artec Eva 3D Scanner

As shown in Fig. 3c, operators must keep an eye on the screen while moving their hands consistently through the process. Failing to maintain the target in proper view or at a correct distance render that scan invalid saving that point-cloud and prompting the operator to restart the scan. This accumulates a number of invalid and incomplete scans on the system all of which are heavy files. Additionally, since this product makes use of Structured Light technology, it is fairly expensive.

Structured Light

The structured light scanning technique uses triangulation to determine the depth of a point on the target surface. It makes use of a pattern that is project onto the target surface and the camera captures the distortion in the pattern based on the nature of the surface. The shifted position of these points is then compared with their original locations thereby creating a 3D point-cloud. This method allows for the simultaneous capture of an entire 3D surface on account of its pattern projection method.

Advantages

Accuracy

Structured light scanning technique allows for adequate accuracy, down to 0.1mm such as in the case of Occipital's Structure Scanner. This, however also depends on the quality of the projector, mainly the lens and the camera that is capturing the patterns as researched by Rocchini in their low-cost design. (Rocchini et al., 2001)

Computational Power

Structured light takes relatively less computational power as compared to photogrammetry or other similar techniques, though the indexing of the pattern for this technology increases complexity quite a bit.

Disadvantages

Pricing

Structured light can be considered quite an expensive setup for the use case and budget being considered which also depends on the projector quality and the camera quality.

D.1.1. Vitronic VITUS 3D Body Scanner (Laser Light)

The Vitus 3D Body Scanner, pictured in Fig. 3d is a laser-light 3D body scanner that consists of 4 scanner modules working in tandem to capture the full body scan of a person. The scanner contains a laser light projector projecting a thin line on the subject as the modules move from up to down. A sensor built into the scanners senses the line on the target creating a depth map. RGB cameras in each of the modules also create a texture map for visualization. The VITUS Body scanner has less than 1mm accuracy in its 4-scanner module version known as the XL and less than 3mm accuracy in a smaller 3-scanner module version. (Maurer, n.d.)

Fig. 3d: Vitronic Vitus 3D Body Scanner

The procedure to get oneself scanned in this scanner includes the following steps:

- The person needs to walk into the scanner cabinet and stand on the platform while the scanner initializes.
- The person needs to stand still as the scanner modules, pictured in Fig. 3e move downwards on their respective pillars while projecting a constant laser line on the subject.
- Once at the bottom, the scanner modules then move back up signaling the end of the scanning process.
- The operator then processes the scan on a software and saves the pointcloud as a .PLY file.

Fig. 3e: Vitus scanner modules on sliders

Something to note with this scanner, other than the fact that this is primarily a full-body scanner is its large size with a maximum frame height of 2.90 meters and base area of 4.84m^2. While it occupies a significant amount of space, it is also one of the more expensive market products, as is visible from the Fig. 3a which is built by a company. The principle, advantages and disadvantages of laser-light technique used in this scanner are further explained below.

Laser Scanning

The laser scanning or laser triangulation technique is quite similar to the structured light technique in that there is a projector that projects a laser and a camera sensor is used to sense the path of the laser line. Then, using triangulation, this shift in position on the sensor can be translated to absolute depth. The camera setup and projector then have to be moved to acquire multiple slices and therefore scan the whole object. Stitching these slices together then forms a 3D surface scan.

Advantages

Accuracy

Laser triangulation is considered relatively accurate with a claimed depth accuracy of 0.04mm(Vukašinović et al., 2010)

Pricing

Laser triangulation systems sell for relatively low prices as compared to some other 3D scanning setups or even just cameras. A turntable-based model is known to sell for 249 dollars (Murobo, n.d.).

Disadvantages

Lighting

Since Laser triangulation systems make use of laser projectors, in this specific case, they could cause discomfort to the subject being scanned since the client also works with photophobic customers who are sensitive to certain wavelengths of light.

Mechanisms

Laser triangulation systems make use of mechanisms to move both the projector and the camera sensor. This could lead to a few problems in the setup being considered here. Firstly, moving mechanisms could lead to possibility of failure thereby making the main function of the machine unusable. Secondly, implementing mechanisms raises costs and complexity w.r.t. maintenance, disassembly/assembly which is also a possible scenario since the product has to be portable.

D.1.2. 3dMDface

The 3dMDface, pictured in Fig. is a 4D face scanner which is also a part of the well-known 3dMD family of scanners. The 3dMDface covers 190 degrees making an ear-to ear acquisition of the face in 4D, so it can also capture facial expressions and speech as well. This scanner consists of 2 modular Camera Units of 6 machine vision cameras alongside an LED lighting system. An accuracy of 0.2mm makes its acquisitions dense and very accurate with an additional ability to capture texture maps as well. (3dMD website)

Fig. 3f: 3dMDface scanner with 2 camera modules and the LED system visible.

The procedure to scan oneself using the 3dMDface is quite similar to the VITUS Body scanner with the difference being that subjects are allowed to move with this scanner due to its ability to capture in 4D.

The shortcomings of this system are its size and price. Despite having just 2 camera modules mounted on a metal frame, this scanner has a considerable length span which could take up a lot of area. As far as pricing is considered, this scanner is amongst the most expensive scanners on the list of scanners mentioned at the start of this section. The 3dMDface makes use of photogrammetry which is explained below in detail.

Photogrammetry

Photogrammetry is a method where multiple cameras are used in order to capture 2D images of the subject from different angles. These images are then sent to a program wherein they are processed to create a 3D point cloud, essentially a 3D reconstruction of the scanned object. This method can capture both mesh and texture with relatively high accuracy.

Advantages

Accuracy

Photogrammetry allows for the creation of highly accurate meshes which are sufficient for the design of products such as eyeglasses.

Speed of Capture

One of the main advantages of photogrammetry is the high speed of capture, approximately 0.001 seconds as mentioned in Khalili's setup using multiple DSLR's covering the complete body. (Zeraatkar & Khalili, 2020)This acquisition time is much faster than other kinds of scanners also discussed in the same paper, such as Artec EVA and the SpaceVision.

Disadvantages

Pricing

Khalili designed a photogrammetry setup making use of multiple DSLRs along with separate dedicated light sources in order to extract the best possible scans from all angles. All this equipment along with the metal mounting frame incur significant costs of prototyping and construction which could translate further into production. The setup designed by Khalili costs approximately 6000 dollars, but another point of consideration is that they design a scanner that covers the whole body. (Zeraatkar & Khalili, 2020)

Manual Image Acquisition

One of the drawbacks of photogrammetry is that the operator is responsible for consciously operating the cameras including taking correct images at the right times. Although framing shots is not a concern in the above-discussed setup since cameras are mounted at regular intervals with ample overlap (about 60%), the operator must still be present for the final shot. (Zeraatkar & Khalili, 2020)

Processing Time

One of the drawbacks of photogrammetry is the processing time it takes after the images are captured.

Passive Stereo

Passive stereo scanners or non-contact passive scanners do not emit any radiation of their own, instead relying on ambient radiation. These scanners work by detecting visible light because it is readily available. However, they also work with other types such as infrared. This is generally considered to be a cheaper alternative because it does not require any particular hardware.

Advantages

Pricing

Passive stereo scanners require no additional hardware to function. Since this technique makes use of ambient light, it can work without laser or light projectors. Conversely, a setup might require multiple such cameras which could still raise the pricing depending on the setup.

Disadvantages

Accuracy & Quality

Passive stereo scanners have relatively lower accuracy as compared to Structured Light Scanners due to the difficulty they face in finding accurate correspondence between stereo images. (Aoki, date)

Appendix E

E.1. Validation

E.1.1. Validation Procedure

Goal

To evaluate the design of the 3D Head-scanner and the experience that little children have when interacting with this product. The aim and intention are for them to have a comfortable, relaxing scanning session where they are not feeling agitated or feeling uncomfortable due to the Head-scanner.

Research Questions:

1. How do children/parents **perceive the product**?
2. Does the 3D Head-scanner **make the children feel comfortable** when they are in close proximity to it?
3. Does the 3D Head-scanner and its **elements have their attention** during the duration of the scan so they are not distracted?
4. What is the **anxiety-inducing element** (as observed in medical products) when they are in close proximity to it/standing “inside” it?

Data Collection Approach & Reasoning

Two different approaches are considered for this validation study, firstly **observation** where a camera will be placed close to the product such that it has the product and the participant in view to note their reactions. The researcher shall only interfere with the camera to start/stop videos for individual participants. Meanwhile the researcher will be instructing the participant/guardian on where to stand, how to approach and what to do while the scan happens. They will stand behind the product in range of both the product and the laptop from which to operate the product. The researcher will not note down anything as all this is happening.

The second approach to data collection is **interviewing** both the child and the guardian. The interview questions will be broken down into two phases, **Pre-scan** and **Post Scan** to get a holistic idea of the scanning experience. The answers to these questions will be recorded by means of a voice recorder on the smartphone. The Pre-Scan questions are aimed at understanding the participant's immediate perception when entering the room and seeing the product or upon taking notice of it. This moment could potentially define the rest of the experience possibly eliciting curiosity, fear, anticipation or indifference. The In-Scan observation would involve observing the child inside the product's range and anticipation factor of the experience. It will talk about what they were hoping to experience, noting negative and positive emotions or analogies to existing products. The Post-Scan questions would revolve around their feeling when stepping out of the scanner and their reactions to seeing their head. Emphasis will be given to their willingness to get themselves rescanned both before they see the head model and after they see their head model on the screen. This would decide whether kids would want to get themselves rescanned after an invalid scan.

Things to Observe

1. Sudden reactions to initially seeing/noticing the scanner. Fear, Anxiety, fidgeting, clinging to guardian, confusion?
2. Reaction to the researcher talking about the product, explaining it and whether they understand it. Then noticing their reactions when they explain it simply such as a camera or photobooth. Showing them the various headscans and checking their reaction.
3. Reaction to showing them how it works. Noticing whether they look at the laptop screen or at the product. Notice whether they talk about the product to their parent or just stay silent. What are they talking about with their parents? What comments are their parents making to reassure them/ convince them, etc.?
4. Reaction to what happens when you are done really quickly and nothing happens. Were they anticipating something? Were they fixed onto the product or the screen?
5. Trying out with their parents and noticing whether they are scared or not.
6. Checking their reaction to when their parents are done. Do they perceive the product as negative or harmful? Are they curious to interact with it?
7. Checking their reaction to when they are told if they want to try it. Willingness towards first time scan.
8. Reaction when asked to look at the element. Are they distracted? Scared? Does the element have their attention? Are they distracted by something else such as the laptop screen or their parent?
9. Reaction to telling them that they are done. Are they relieved? Are they smiling, confused or running to their parents?
10. Reaction to asking them if they want to do it again? Showing head and asking again. Willingness to rescan.

Interview Questions

1. **What do you think this product is?**

Not sure. Could be scary for children. Reminds f a dentist instrument.

2. **What do you think the product does?**

Show them how the product works by testing on yourself or on their guardian. Show them the head on the screen. Explain in basic terms by drawing examples to things such as photobooths, etc.

3. **Do you understand what the product does?**

If No, then explain to them how it works in the simplest terms.

4. **Would you like to try it out/play with it/make a picture with it?**

*If No, then ask **Why not**. Be reassuring. If **Yes**, then continue.*

Take the child to the scanner, notice whether the element draws their attention. Lower the scanner down or not depending on randomization. If not attracted, draw the kid's attention to the laptop screen and show them how it is changing with their position. Ask them to look back at the element. Tap Q to Capture.

Tell the child you are done. Reassure them.

5. **How are you feeling?**
6. **What did you think about that experience?**

If they don't give a straight response, do not ask again. Notice if they talk to their parents about it. Check for possible expectations.

7. **Would you like to try that again?**

If NO, then wait to show them the Head scan. Once they see it, ask again. If YES, retake the scan and check whether they learned how to use it.

8. **How do you feel about the product now?**

Questions for the parents

1. **What does this product look like/resemble to you?**
2. **Do you understand what this product is doing? How it is working?**
3. **Does this look safe for your child to use?**
4. **Would you like your child to use this product again?**
5. **What part of the device feels unsafe/unsure to you?**
6. **Which of the 2 devices would you prefer for your child to use for the scanning process and why?**
7. **What do you think about the speed of the device as compared to the other one?**
8. ***[Explain use case of the device]* What are some points that you LIKE about this device as compared to the Structure Sensor?**

9. **What are some points that you DON'T LIKE about this device as compared to the Structure Sensor?**
10. **What do you think of the scan quality?**
11. **Do you have some remarks/comments about the device?**

E.1.1. Validation Session 1

1. **What does this product look like/resemble to you?**

It's interesting but the rest is totally new. Doesn't look like anything he has seen before

2. **Do you understand what this product is doing? How it is working?**

I am trying to understand but I am not sure. That's why I was asking can you show me what was happening on the screen. Once I saw how it works, I have a better understanding.

3. **Does this look safe for your child to use?**

I think so. There's no problem.

4. **Which of the 2 devices would you prefer for your child to use for the scanning process and why?**

Both are okay, if the final result is the best one, I have no preferences. For my daughter, both are okay.

5. **What do you think about the speed of the device as compared to the other one?**

You need to learnt the Head-scanner and you already know the Structure Sensor so it is not fair to compare.

6. ***[Explain use case of the device]* What are some points that you LIKE about this device as compared to the Structure Sensor?**
7. **What are some points that you DON'T LIKE about this device as compared to the Structure Sensor?**
8. **What do you think of the scan quality?**

The one from the Headscanner is not quite as good as the Structure Sensor, not quite there yet.

9. **Do you have some remarks/comments about the device?**

No remarks.

E.1.2. Validation Session 2

1. **What does this product look like/resemble to you?**

It looks like a space-craft. I think it's a bit big. I was not expecting that it has 2 side cameras as well, only that it has one. But it looks Spacey, also because of the colour. I expected Black. Maybe choose better colours for younger kids.

2. **Would you say this looks more medical right now?**

Yes. Like with a dentist, you also have this colour. It doesn't have to look like a medical device, like you see in those new MRI scanners from Philips with music and very colourful. It is interesting if you can do more with an experience like with headphones or relaxing music. It also helps to focus kids.

3. **Do you understand what this product is doing? How it is working?**

Yes, I know, it works with Photogrammetry.

4. **Does this look safe for your child to use?**

It does because it is non-contact but it does sort of agitate her when she sees it so maybe there it could be improved. If it did not go all the way around the head, that would probably make her feel more comfortable.

5. **Which of the 2 devices would you prefer for your child to use for the scanning process and why?**

I don't really think one is better than the other. The Headscanner is fast but the Structure Sensor is less intrusive because it is farther away. His wife prefers the Head-scanner because it is just one press on the button and it is easier to adjust if she moves unlike the one with Pieter where he has to do it again and again.

6. **What do you think of the scan quality?**

It is hard to say because the ones from the Head-scanner is really small. But the quality from Pieter's scanner looks much clearer. From Pieter's scanner, you can easily tell whose scan it is but from the Headscanner, one has to sort of see and they feel maybe the scan didn't come out properly.

7. **Do you have some remarks/comments about the device?**

It doesn't matter what it looks like as long as it works. As long as it is working for my daughter and giving good glasses, it is completely fine. Need to do more color investigation.

E.1.3. Validation Session 3

1. **What does this product look like/resemble to you?**

   It looks very futuristic, sort of looks like a dentist's instrument that goes around the teeth which has a little bit of radiation. That's why I was wondering if it has radiation.

2. **Do you understand what this product is doing? How it is working?**

   I sort of do. I was wondering how you can capture all sides of the face simultaneously so I could see it.

3. **Does this look safe for your child to use?**
   Yes, I only want to make sure that there is no radiation.

4. **Which of the 2 devices would you prefer for your child to use for the scanning process and why?**
   The Headscanner is much easier than the Structure Sensor. For the Structure Sensor, you have to be quiet and hold your breath. Takes a little bit more effort because you keep your head still. The Headscanner is a bit faster and so less difficult for the subject.

   I would be willing to try this device out a second time if my first scan is not good.

5. **Do you have some remarks/comments about the device?**

It is very easy to use and very fast. Especially for people who have difficulty keeping still, it is very easy to use.

Appendix F

F.1. Interviews with Clients

F1.1. Peter from Maatbril

Section 0 - General

Depends on the lead.

1. We're present at a clinic in Down Poli and people who come in for an eye measurement(prescription) get a scan done afterwards.
2. They sometimes send a mail through a website or contact through Facebook and then go to their house to get the scan or even to the child's school or care home and get a scan done.

For grown-ups, mostly always go to the care-home to get a scan done.

Section 1 – Portability & Travel

North of Holland or South. North in Amsterdam to Groningen or South, Amsterdam or Maastricht. Always travel for batches of scan, never just one scan.

Always scan people in loops/ batches, so 3 or 4 visits in a day, either delivering glasses or scanning.

Ideal scenario is a common scanning station where people come to get scans and collect glasses.

Have to go to client to check if glasses fit as well.

All this physical movement to and from the client, fitting error, redesign, etc. relies heavily on a good initial scan.

b. Carry the scanner, iPad and the boxes with different glasses for demos, color cards. All carried in a box. Don't really use a laptop, only iPad works since there is no post-processing in the client's home. Software like Hubspot works.

c. Always go to client's houses. Clients don't have to go anywhere or they make sure Maat is at the eye measurement center when client comes there.

Section 2 – Pre-Scan

Arrive at the customer, talk with them, attach the scanner on the iPad. Talk about the process, what they'll do. Show them one or 2 scans, let them play with it a bit. Tends to calm the user. Show them their scans, also show them how to sit very still for 10 seconds for a good scan.

2-3-year old kids keep moving all the time. Doesn't give a good scan.

In those cases, they make them watch a video. But sometimes, they play music but kids start clapping or singing along which is not good and works counter-effectively.

Operator makes a whistle or a sound and scans in the meanwhile while the client is distracted by it.

Sometimes ask the mother or father to hold their head. Ask them to lay down sometimes on the bed or on the lap.

Kid can also move their head from side to side but need to be very steady, like a turntable which is very difficult to do, even for a normal human.

Gyroscope in scanner and iPad helps to scan from different angles and yaw, pitch, roll.

Some kids really sit still, some move and others can't sit still, maybe conditions like spasms, or muscle conditions, etc**.**

Really quick to attach the scanner, about 5-6 seconds. Explaining takes longer, not too quickly because takes time, and too quick can cause stress in the client and parents. So, explaining to parents and kids is important.

If clients have toys, they start to play more with the toy instead of focusing with the session. So parents are mostly nervous even with small movements (which are usually fine) and tell them to sit still which makes the kids even more nervous. Disconnect between parents and children.

Sometimes ask the parents to go drink coffee and keep themselves busy because the kid is sometimes fine on his own. Doesn't always work.

Hardest fact is kid himself has to want to sit still.

There is a disconnect in the process understanding between parents and operator which makes parents more nervous even if the situation is usually okay.

Sometimes operator asks parents how the kid can be comforted. Watching video? Playing music? Not watching, etc.?

Section 3 – During Scan

Operator can completely focus on the scanning. Scanner detects when the kid is moving(by showing it on scan) and gives you very good feedback.

Sometimes have to stop mid scan and wait till the kid is calm to start a new scan.

Operator can also take bursts of scan of different sides of head and stitch them later. Not ideal. More like last option. 1 in 5 or 6 cases need this approach. **IMPORTANT.** Also lie in bed.

Eyes need to be open for face recognition and measurement, also for lens positioning between eyes and bridge, right and left ear and the nose(bridge). These are landmarks.

Manual aligning approach in cases with no ears (like glasses).

Face recognition is more for automation but also for the 3d scan sometimes. Also distance between bridge and pupils is needed to align the lenses and eventually the spectacle design.

Takes 6 seconds to finish scan on a very ideal case. Could take more for actual clients (needs to be measured in an actual session).

Clients start to move their heads after 2 or 3 seconds. But they do try to sit still initially.

Parents are present, sometimes try to help, distract the kids. They stand behind operator and hold a iPhone/device (show movie) to distract the kid. Sometimes support the kid to help with the scan, support their head, put them on their lap, etc.

Section 4- Post Scan

Might have to go back to a scan redo. Once you are happy with the scan, they take demo glasses, and ask the client on shape, colour, design. Client has to choose from one of the given designs only, never a custom shape. Only special needs are custom designed into the glasses, like different frames, etc.

Make sure they have the eye measurement, prescription(power) from the client. Also ask them to mail it separately to Maat!

Section 5 – Client/Child or Adult

Clients really like interacting with iPad, and 3D scans, the 3D scanner. They find it funny.

Operator are usually silent throughout the process, but also count during the process, or whistle or something to focus the client's attention.

They need things to keep them still. But too many things distract them or they start playing with them.

Section 6 - Parent

Parents try to help, get nervous or irritated by kids moving. They start to get anxious but sometimes they want to help but make it worse. They feel that this is not working out, maybe the child is inconveniencing the operator.

Parents are open with operators interacting with the kids.

Section 7 – About the Brief

Down Syndrome, some of them have more difficulty sitting still than others. But all have a very limited attention span. Some can sit still but not longer than 6-7 seconds max.

Section 7 – Client Relations

After scan is done, clients are asked to send prescription to Maat! who meanwhile process the scan and assign a spectacle template to it. After that, they design the smaller details according to the scan such as temple tips, the area around the ears, the nose bridge and length and thickness of the glasses. This design is then sent to Materialise to be 3D printed after which it comes back. The lenses are also sent to Maat from the optician's place and Maat then paint the glasses and manually fit the lenses.

They then go to the client's place for a fitting session and to see if any changes can be made. If not, then they redesign changes and come back. If yes, then the glasses are given to them.

Section 8 – Process/ Wishes

Don't really want to travel. Could have a scan booth which is like taking a photo. Anyone can use it. This would allow operators to train other people to make scans, increase the accuracy of scans, also good for clients, don't sit still, also for parents. Can eliminate a lot of problems.

Really, the driving is one of the biggest problems.

Have the client involved more in the process, show demos, already show them demos before the process.

Preferably, 100 percent digitally. Train someone to do this at their homes. Ideal if everybody can use it. Choosing this is always good.

Could be self-done by parents as well. *Too good scenario(?)*

Possibility to train someone else to do this. Needs to be easy to do.

Initial Assumptive Requirements

1. Need a **directed distraction**, something to engage.
2. Needs to be just enough to not over-distract the client, over-express emotions of joy, fear or excitement.
3. Needs to be easy to use, understand and get an output out of. For operators and for clients and parents as well.
4. Needs to be playful(?), not medical or mechanical. Shown through colors, lighting, movement, responding to children?
5. Connect with clients on a basic, familiar level.
6. How can it involve the client/parent into the process? Induce indirect interaction?
7. How can it affect the parents in a positive way as well?
8. Needs to be really quick, grasp opportunities to take a scan.
9. Needs to be accurate, collect all the important required data.
10. Needs to be easy to setup. Not longer than the existing setup time of the Structure Sensor.
11. Needs to be easy to explain. Needs to connect with clients and parents to make them feel familiar.
12. Needs to be easy to carry. Modular setup? Telescopic? Easy to pack and go?
13. Needs to suit most of the contexts and postures. Hospital room, living room, bedroom, on the bed, sitting, standing, etc.
14. Maybe tell a story? Connected to a cartoon story playing on a screen which prompts the kids to look at a specific camera which responds back? Like a show? Complete digital and physical experience? Too heavy on operator? Too much of a setup context?
15. Should not be confusing, and so distracting to the client.
16. How can the setup be simpler?
17. Could have an adult client variant? Less playful, less storytelling, still engaging?
18. Needs to be light on mechanisms OR no automated mechanisms to reduce costs and chances of failure.
19. Needs to be easy to manufacture. Simple design, simple moulds, etc.

F.2. Observation Session 1

F.2.1. Observation Session 1- Tom- 19 years

14:33:10 Tom does not speak, but instead moves to take his jacket and notices us.

14:33:30 Jan Berend explains process to his dad, the lady and Tom. Shows scans and photos. Explains all the landmarks he'll be capturing.

-Explains the process to Tom. He gives no response, just stays there.

-Tom suddenly reacts.

-JB explains the process to him. He points to something saying he understands.

-JB starts scan. The lady distracts Tom to keep him looking forward and JB asks her to. He stays still and moves at the last second.

-Scan done. JB fills in the family details on the iPad.

-JB shows Tom's scan to him. He sees it.

-Tom understands. Another scan starts. Family members talking to him. His father stands up and starts to arrange his head and distracting him while the scan happens.

-JB scans his right side more carefully.

-Scan done.

-Another scan starts, the parents talk to Tom constantly.

-JB scan left side and Tom turns his head at the last minute. Scan invalid**. It is important to capture the pupils in the scan to align the focus of the glasses**, that's why so many scans.

-New scan. All sides came off perfectly. Parent asked for this last scan. JB seems to face problems scanning left side because of a table there where he cannot move.

-Filling in details. Shows scan to parents and explains the landmarks.

Overall JB took 3 scans of Tom.

-Again, shows scans and explains something about the nose anatomy to the father.

Tom standing there throughout.

-JB takes a photo of Tom.

-Tom points to another iPad on the table. There's 2 iPads attached on the table along with a speaker.

-Father starts a show on the iPad. Tom wants to change it. JB just sitting and observing everything.

-Tom wants to dance with the lady. He turns up the volume in the speaker.

-Tom dances with everyone.

-Still dancing.

-Tom understands how electronics work.

-Still dancing.

-JB takes out case with frames.

-Dancing to new song.

-Tom sits down to see new frames.

-JB fits frames to Tom to check the color. There's a mirror on the inside of the case.

-Dad brings his phone to video call Mom for the viewing as well.

-Dad calls Mom to show her the glasses.

-JB explains frame models to Mom on call while outing frames on Tom.

-Still testing frames.

-Explaining something to Mom about glasses.

-Dad brings eye power prescription to JB.

-Still explaining the process and post-scan things.

-JB goes to get silicon for behind ear measurement.

-JB takes out silicon from 2 containers, green and white.

-JB explains silicon process to Tom. Tom takes silicon and plays with it. Shows it to mom then gives it back.

-JB applies silicon behind Tom's ear.

-Applies silicon behind second ear. Tom takes it from JB and plays with it.

-JB removes both silicon shows it to everyone.

-My introduction.

-Session OVER.

F.2.2. Observation Session 2 – Lady

16:18 -JB explains process to the lady.

-She wants to get to the point.

-JB gives her glasses to try.

-More glasses to try. She likes or rejects.

-Tries to say something.

-JB going to start scanning. Explains the process to caretaker.

-JB asks lady to sit on the chair facing the light. She does. He asks her to keep a very straight face.

-JB starts scan, within seconds, lady suddenly jumps up from her chair and goes and sits back on her old chair. **Triggered by something?**

-JB discusses something with the caretaker.

-JB packs things up.

-Scan UNSUCCESFUL.