Designing a casing for the control unit of a virtual reality system for use in a hospital

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VOORWOORD

Na een paar maanden van hard werken is hij dan eindelijk af: de thesis voor mijn bachelor opdracht. Met veel plezier heb ik de afgelopen tijd gewerkt aan deze opdracht en ik wil Cinoptics dan ook bedanken voor de mogelijkheid om mijn bachelor opdracht bij hun te komen doen. Ik heb veel geleerd tijdens deze opdracht zowel op het ontwerpvlak als over de technieken rondom virtual reality die mij voorheen nog onduidelijk waren. Ik hoop dat mijn onderzoek en mijn ontwerp het bedrijf verder kan helpen in het realiseren van een nieuwe virtual reality opstelling voor het HBK-project en dat mijn onderzoek een nuttige toevoeging zal zijn voor bedrijf Cinoptics als geheel.

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Dan rest mij niet meer dan de lezer van dit verslag veel plezier te wensen met het lezen van deze thesis. Mochten er vragen of opmerkingen zijn, twijfel dan niet om contact met mij op te nemen via het volgende mail adres: c.h.c.l.vanoorschot@student.utwente.nl

Cyriel van Oorschot, 5 oktober 2014

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SUMMARY

In this assignment, a casing will be designed for Cinoptics for the controller of a Virtual Reality system. This assignment is part of the HBK-project which is financed by the foundation ‘Help Brandwonden Kids’. This project, in cooperation with the University Hospital in Leuven (UZ Leuven), is about improving the experience of the patient during the treatment of the burns of children. Using a game which is played with a head mounted display (also referred to as Virtual Reality headset or HMD), children will be distracted from the medical treatment and the pain experience will be reduced. The project is running for a few years now at the UZ Leuven and the next step in the process is to design an easy to handle controller that contains all electronic components which are needed in order to play the game.

UZ Leuven has been testing with a older version of this VR-system for a while. They have been able to identify a couple of problems after testing this setup with both patients and non-patients. A problem that has been identified, is the difficulty of cleaning the current setup. There are several hygiene regulations that must be met. In hospitals, chlorine and alcohol are used to disinfect products like the controller. These measures influence the chosen materials for the product. Setting up the current system is proven to be time-consuming and the personnel needs too much time to set up the VR-system. Another major problem is that the medical practitioners are not able to see the video images of the game that the patient is playing.

Cinoptics already has a set of electronic components which are needed for the system to operate: a tablet to play the game and electronics which will ensure that the HMD can receive the video signal. During this assignment a battery, which ensures that the system can be used wirelessly, was added to this list.

In order to generate ideas, the problem was divided into nine sub-problems. Through brainstorms, solutions were found and through morphological analysis, a choice was made between the different solutions and these chosen solutions were combined to form concepts. In addition to this method, other solutions were formed by looking at the configuration of different components in the controller. With this method, another couple of concepts have been developed.

Eventually four concepts where designed and they were compared to each other in different ways together with Cinoptics and a choice was made for a final design. It was necessary to elaborate a few aspects of the design. The docking mechanism for the tablet, material and production method and the starting mechanism needed more detail. A small research was conducted in order to select possible materials and together with a research into several production methods it appeared that the best solution for producing the final product is vacuum casting with the use of silicone moulding. For this poly urethane (PU) can be used as a material. A company was found that could produce the prototypes as well as the final product in the desired materials.

After this a 3D model was made in Solidworks. This model can be used as a starting point for production of the first prototype en also gives a good image of the appearance of the final product. Finally a brochure is made that enables Cinoptics to inform hospitals and other possible partners about the new product in the portfolio of Cinoptics.

NEDERLANDSE SAMENVATTING

In deze opdracht wordt voor Cinoptics een casing ontworpen voor de controller van een virtual reality systeem. Deze opdracht is onderdeel van het HBK-project dat gefinancierd wordt door de stichting Help Brandwonden Kids. In dit project, waarin wordt samengewerkt met het Universitair Ziekenhuis Leuven, wordt gewerkt aan het verbeteren van de patiënt ervaring tijdens de behandeling van kinderen met brandwonden. Door gebruik te maken van spel dat gespeeld wordt via een head mounted display (ook wel virtual reality bril genoemd of HMD) worden kinderen afgeleid van de medische behandeling en kan de pijn ervaring worden verminderd. Het project loopt al enige tijd bij het UZ Leuven en de volgende stap in het proces is het ontwerpen van een handzame controller die alle elektronische onderdelen bevat die nodig zijn om het spel aan te sturen.

Het UZ Leuven heeft al testen uit kunnen voeren met een ouder versie van het VR systeem. Hieruit zijn een aantal problemen geïdentificeerd na het testen van de opstelling bij zowel patiënten als niet patiënten. Een belangrijk probleem is dat de huidige opstelling moeilijk schoon te maken is. Er moet voldaan worden aan allerlei hygiëne maatregelen. In de ziekenhuizen wordt chloor en alcohol gebruikt om producten zoals de controller te desinfecteren. Deze maatregelen hebben invloed op materiaalgebruik in het product. Ook het opzetten van de opstelling is tijdrovend en personeel is lang bezig met het klaar maken van het VR systeem. En ander groot probleem is dat de behandelaren niet goed kunnen meekijken bij het spel dat de patiënt aan het spelen is.

Cinoptics heeft al een opzet gemaakt van alle elektronische onderdelen die nodig zijn om het systeem te laten werken: een tablet om het spel te draaien en enkele elektronische onderdelen die ervoor zorgen dat het videosignaal goed aankomt bij de HMD. Aan deze lijst is tijdens de opdracht een accu toegevoegd die ervoor zorgt dat het systeem draadloos gebruikt kan worden.

Om ideeën te generen is het probleem opgedeeld in een negental subproblemen. Hiervoor zijn via brainstorms oplossingen bedacht. Met behulp van een morfologische analyse is een keuze gemaakt tussen de verschillende ideeën die samengevoegd zijn tot concepten. Naast deze methode is er ook een oplossingsroute bedacht door te kijken naar de configuratie van de verschillende onderdelen in de controller. Ook met deze methode is een aantal productconcepten bedacht.

Door de vier uiteindelijke concepten op verschillende manieren te vergelijken in overleg met Cinoptics met elkaar is uiteindelijk een keuze gemaakt voor een definitief ontwerp. Hierbij was het nodig om een aantal zaken verder uit te werken. Zo moest het dockingssysteem voor het tablet, de materiaal en productie methode en het startmechanisme worden gedetailleerd. Voor de materiaal keuze is een klein onderzoek gedaan naar mogelijk materialen en in combinatie met een onderzoek naar productiemethode is gebleken dat de beste productiemethode voor het uiteindelijk product vacuüm gieten met behulp van een silicone mal is en hiervoor kan poly urethaan (PU) gebruikt worden als materiaal. Voor de productie is een bedrijf gevonden dat zowel de prototypes als de uiteindelijke producten kan produceren in de gewenste materialen.

Hierna is er een 3D model gemaakt in Solidworks. Dit model kan worden gebruikt als uitgangspunt voor de productie van een eerste prototype en geeft tevens een goed beeld van het uiterlijk van het product. Als laatste is een brochure gemaakt die het mogelijk maakt om ziekenhuizen en andere partners te informeren over het nieuw product in het portfolio van Cinoptics.

1 INTRODUCTION

In this chapter a description of the starting point for this assignment will be given. First an overview will be made of the history of Cybermind. Who is Cybermind and what are the long- en short-term goals of the HBK project.

From September 2014 the corporate identity of Cybermind will change together with the name of the company. It is important to take the changes into account when designing the new controller for the virtual reality system.

Virtual reality and its use in pain relief is also described together with an earlier prototype from the hand of Cybermind. The old version of the virtual reality system, which is tested in two Belgium hospitals, will function as starting point for the design of the new virtual reality system.

Finally the goal of this specific assignment will be specified.

1.1 BACKGROUND OF COMMISSIONING COMPANY

1.1.1 HISTORY OF CYBERMIND INTERACTIVE NEDERLAND

Since April 1997 Cybermind Interactive Nederland is producing products and services for the virtual reality market. The main scope for virtual reality in the late 90's is the leisure market. Virtual reality headsets in this time are mainly used for gaming, mostly in arcade halls. Some product examples of Cybermind are shown in *figure 1.1*. In the Benelux Cybermind is the leading producer of virtual reality accessories and virtual reality entertainment systems. Besides this entertainment segment Cybermind also investigates the possibility of using virtual reality in the professional market (researchers, developers and educating purposes).

Figure 1.1 | Examples of virtual reality entertainment systems for arcade halls made by Cybermind Interactive Nederland in the late 90's

With the beginning of the new millennium Cybermind (and other virtual reality developers) noticed that the entertainment market was not yet ready for application of virtual reality. Although many of Cyberminds systems were used for events, exhibitions and symposia the demand for virtual reality systems was too small in order to make big steps in production. That is why Cybermind started to focus more on the professional market rather than the leisure market.

This soon turned out to be a good choice and Cybermind could keep his position at the top of the market. They kept growing as a company and settled at different places in the

Netherlands. Currently their head office is settled in Almere and the production facility for the optics of the virtual reality headsets is located in Maastricht and in Leeuwarden the development of all the electronic hardware and the assembly takes place. Cybermind is also settled at two universities for research purposes: TU Delft and University of Twente.

A new era began when Cybermind presented their newest head mounted display (HMD) in 2003: the Vissette45. With this HMD the first affordable virtual reality headset had been introduced and on top of that it was the first HMD with see trough possibilities. This HMD functioned as a starting point for many product that Cybermind produced (see *table 1.1*).

Table 1.1 | Overview of latest product line Cybermind

Afbeelding	Beschrijving
	***Visette45SXGA*** The Visette series offers an affordable high-end Head Mounted Display (HMD). It's key features are: the flexible design which enables us to integrate seamlessly the InertiaCube3™ head tracking device (optional) with custom solutions for Polhemus, Ascension and the IntertiaCube2
	***Virtual Binoculair:s VB-56 SXGA*** The FLCoS display technology is incorporated in our first Virtual Binocular model. It's amazing 56 degrees Field of View in combination with the high resolution makes it the ideal tool for research and training applications. The VB-56SXGA allows seamless integration of a wide range of precision trackers and supports all resolutions up to SXGA.
	***Simulated Night Vision Goggles: SIM NVG*** Cybermind introduces the first Simulated Night Vision Goggle based on FLCoS SXGA Micro Display Technology with 40 degrees Circular Field of View. Compatible with DVI and RGB input, offering the best image & Black Level seen in Simulated NVGs to-date. The ideal solution for pilot training, designed and based on the input of real pilots applications includes: ▪ Full Motion Training Simulators ▪ Mid-Range Training Simulators
	***Cyber-I SXGA Monocular HMD*** Cyber-I SXGA Monocular HMD is the first SXGA Optical See-Through Monocular with fixed camera option and 50 degrees Field of View. It is compatible with HDMI out (smartphones and tablets) and the optical solution for hands free applications for the Homeland Security and Defence Industry, maintenance- and logistics applications and to support medical procedures.

These developments have resulted in the company that is know today. Cybermind is currently dividing their products into four segments: 'defence', 'medical', 'industrial' and 'aviation'. Medical and defence are the largest segments of the company. This assignment takes place in the medical segment.

In September 2014 Cybermind will change its company name. Together with a new vision and new mission the company wants to clarify a new approach concerning virtual reality. The first product line that is presented with the new brand consists of four new products of which one is the product that is developed during this assignment.

1.1.2 NEW COMPANY NAME AND CORPORATE IDENTITY

The old branding of Cybermind Interactive Nederland originated back from 1997. The connection between the corporate identity and the products that Cybermind produced was lost and therefore a new corporate identity was created. An overview of this new identity can be found in *appendix H*.

When designing the new product in this assignment is important to connect with the new corporate identity of Cinoptics. The new VR system is one of the first product of CInoptics and must represent the new mission and vision. For instance, making use of the colour scheme could connect the product and the company.

1.2 VIRTUAL REALITY AND ITS USE IN PAIN RELIEF

1.2.1 VIRTUAL REALITY

Virtual reality (in short: 'VR') or virtual environment is the concept of using computer technology to create a simulated, three-dimensional world that a user can manipulate and explore while feeling as if he were in that world. Opinions differ on what exactly defines virtual reality. In general virtual reality should include the following:

- Three-dimensional images that appear to be life-sized from the perspective of the user
- The ability to track a user's motion, particularly his head and eye movements, and correspondingly adjust the images on the user's display to reflect the change in perspective.

The goal of a virtual environment is to create a feeling of immersion. The user must feel like he is being inside and part of another world. Also is must be possible that he interacts with this environment. This feeling is called as telepresence. Jonathan Steuer, a computer scientist, studied this telepresence. He defined two main components that were part of immersion which were depth of information en breadth of information.

Depth of information stands for the amount and the quality of the data signals that the user receives when experiencing a virtual environment. For example, this refers to the resolution of a display and the complexity of graphics in the environment. Breath of information is defined as the number of sensory dimensions simultaneously presented. For instance, a virtual environment experience has the most breath when al senses are stimulated.

Other important facets of telepresence are 3D sound and latency. Whilst in a virtual environment the user must be convinced that the sound's orientation shifts in a natural way as he manoeuvres through the environment. Latency is the time between an action of the user and the response of the virtual environment. An example of latency is the time between a user moving his head and the system responding by changing the point of view.

These four aspects (depth of information, breath of information, 3D sound, latency and interactivity) contributed to the immersive feeling a user experiences while being in a virtual environment.

1.2.2 VIRTUAL REALITY IN ANALGESIA

The concept of virtual reality have been around for decades (the first stereoscopic system that showed 3D images dates from 1960s), however public awareness about VR only started round the early 1990s. This is also the time that virtual reality found its way into the medical world. The use of virtual reality in combination with analgesia (the medical term for the absence of sense of pain) first came up about ten years ago. So research in this area is still very young.

VR analgesia consist of intensely stimulating as many senses as possible of the treated patient and by doing so creating total immersion around the patient with the purpose of 'forgetting' the pain during a (medical) treatment. The patient will imagine himself in another world and is no longer aware of the real world surrounding him. With the use of a head mounted display (HMD), music, sound effects and tracking the patient's head movement this experiences is brought to its full potential.

Different researches have tried to figure out what exactly happens when patients find themselves in a virtual environment en why feelings of pain are reduced. Melzack and Wall set up the Gate Control Theory. This theory states that pain is made up of the following: the amount of attention spend on the pain, the emotion that is accompanied with the pain and experiences you have had in the past with pain. McCaul and Malott expanded this theory with the statement that people have a limited amount of attention that they can spread across any stimuli they undergo. By distracting patients with other stimuli than pain a state can be achieved where pain does not get any attention.

Because of the reason that VR analgesia is still in its infancy there are little studies held studying the results of VR analgesia. Also the sample size of these studies are relatively small and therefore little can be said about the effectiveness of VR analgesia. In most studies VR systems are used during treatment of burns and less is known about using VR analgesia in other areas.

Cybermind has done some research in collaboration with two hospitals in Belgium. The description and results of this research can be found in *paragraph 2.1.2*.

The few studies that have been held around the world give very positive results and de main conclusion of these studies are that a lot of patients experience less pain when using a VR system during painful treatment. Researchers suggested the following preliminary conclusions:

- VR analgesia does not weaken during multiple sessions,
- Pain revalidation is quicker in comparison with treatment without VR
- Patients are more mobile during treatment with the use of VR analgesia
- Treatment of burns has a longer effect (patients tend to experience less pain for a longer amount of time)

There must be noticed that VR systems are quite expensive systems for burn centres and due to lack of research burn centres will not invest quickly in VR analgesia . When more VR systems are available for research in hospitals then there is more room for studies about this way of pain analgesia and a larger sample can be achieved. Parallel to this there need to be more research about the neurosystems that play a role during VR analgesia. In this way it is possible to get a better view on pain an pain analgesia using VR. Luckily we see more and more researches who are interested in this form of analgesia and hopefully this will lead to better understanding of VR analgesia.

1.2.3 GRAVILO AND GOAL OF THE HBK-PROJECT.

This assignment is part of the HBK-project. HBK (Help Brandwonden Kids) is a foundation that supports this project by financial means (more information about HBK as an stakeholder can be found in *paragraph 2.2.2*). Project HBK is executed by two parties: Cybermind Interactive NL and Gravillo. The main goal of the HBK-project is the successful application of Serious Games with the aim to reduce pain in clinical care / treatment of burns. In this project Gravillo develops the software that is going to be used during this treatment. Gravillo is currently developing a whole range of Serious Games that is going to be used at burn treatments with child patients. In *appendix A* you can find all the games that are developed for the HBK-project with a short description.

For one of these games, Snowball Bash, Cybermind is asked to develop a virtual reality system in order to play the game. Cybermind already developed a similar VR system for a similar serious game back in 2004 and in this project a new version of this VR system is going to be designed.

The goal will be to place the new system into various hospitals en its primary use will be to reduce the pain form patients during burn treatment. Alongside academic research will take place to further develop the VR system and to learn more about VR analgesia.

1.3 PROJECT STATUS AND GOAL OF THIS ASSIGNMENT

1.3.1 PROJECT STATUS

A few years ago Cybermind developed a similar VR system as the one that is going to be designed in the assignment. In this system the vissette45 was used (*see table 1.1*) and an improvised controller was developed (see *figure 1.4*). The visette45 is HMD which originates from 2003. The controller was nothing more than a big cart (called the Pro Cart) were all hardware was stored that was necessary in order to control the HMD. A prototype was put together and tested at the burn centre of UZ Leuven.

Figure 1.4 | Two main components of the old VR system. Left the vistette45 and on the right the Pro Cart

Gravillo just finished with the development of the software and Cybermind already investigated which hardware is needed for the new VR system. The last step to completion of the VR system is making a design for the HMD and the controller. When this is finished prototypes can be made for hospitals and these hospitals can then continue their studies to pain analgesia using virtual reality.

1.3.2 GOAL OF THIS ASSIGNMENT

The goal of this assignment is to design a casing for the controller in the new VR system, in other words a next version of the Pro Cart will be developed. This will happen simultaneously with the development of the new HMD. The controller will be a product which allows the medical practitioners to control the serious game that the patient is playing and see what the patient is seeing. The new controller also contains all electronic hardware necessary to use the HMD.

1.4 CONCLUSION AND FURTHER READING

Cybermind Interactive Nederland is one of the leading companies in virtual reality solutions. Started in 1997 they have become the largest VR supplier in the Benelux with establishments all over the Netherlands. In the course of time the focus of Cybermind shifted from the leisure market to the professional market and currently their focus lays at their defence segment and their medical segment. Due to this shift Cybermind has chosen to change their corporate identity to make sure this corresponds with their new product line. Cybermind changed their company name to Cinoptics in September 2014.

Within virtual reality experiencing total immersion is the most important to a successful VR experience. This immersion can be achieved by completely submerge the user by using as many senses as possible. The application of VR in analgesia is still very young and researchers are still studying the effects. Only small samples are used in studies so it is hard to really state conclusions. But preliminary conclusions are very positive and analgesia by using VR is very promising.

That is why Cybermind wants to keep developing in this area of expertise. After a promising first prototype that is tested in UZ Leuzen Cybermind wants to design a second prototype. With financial support of foundation Help Brandwonden Kids and a partnership with the software developer Gravilo a new VR system is being developed. In this assignment a new design for the casing of the VR system will be made. Together with the new HMD, this must become the one of the new products in the first product line of Cinoptics.

RESEARCH AND ANALYSIS

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In this section of the report we will look at the research preliminary to the design of the casing. Firstly the old virtual reality system is reviewed. This old prototype has been tested in the UZ Leuven. A conclusion of this evaluation will be described as well as an interview with the medical practitioners that treated the patients using the old virtual reality system.

Secondly an analysis will be made about the users and surroundings. The target group and stakeholders will be described so all interest can be mapped. In the third paragraph the properties of the new system are written down together with an analysis of the functions and user-product interactions.

In the fourth and last paragraph a list has been made of all the requirement and wishes that are extracted out of the research that is done. This will result in a product description that functions as a starting point for the idea generation.

2.1 EXPERIENCES WITH OLD VR SYSTEM

2.1.1 DESPRICPTION OF OLD VR SYSTEM

The old VR system consisted of two main components. The visette45 (an head mounted display developed by Cybermind) and an improvised cart (called the Pro Cart) were all the hardware was stored. In *figure 2.1* you can see these two components.

Figure 2.1 | Two main components of the old VR system. Left the vistette45 and on the right the Pro Cart

Cybermind Pro Cart
The Pro-Cart was temporary solution for storing all the hardware that was necessary to run the game on the HMD and being able to transport it throughout the hospital. In this version of the VR system the different components, like the cable splitter and head tracker, were very large. The car stores the following hardware: a isolation transformer, laptop, cable splitter, head tracker, HMD and cables. More specific information about the cart can be found in *appendix B*.

2.1.2 USER EVALUATION OF OLD VR SYSTEM

Evaluation UZ Leuven
In 2011 the old prototype was brought to the UZ Leuven with the purpose of testing the VR system and studying the effects of the system on pain analgesia. Unfortunately it appeared difficult to find patients who fit the requirements to take tests with the VR system. The main reasons were that patients were not interested in using the VR system or the HMD couldn't be applied on the small heads of some children. As a solution a group of non-patients was used to get some test results for the survey. In *table 2.1* the distribution of the test subjects can be found.

Table 2.1 | Overview of test subjects that used the VR system in UZ Leuven

Test subjects	Duration of test	Comments on test group
Non-patients		
17 adults	5 minutes	Staff of the burn centre, 2 colleges kinesitherapy
5 children (5-10 years)	10 minutes	Children of the staff of the burn centre
Patients		
1 adult	Not known	
1 child	Not known	

This test was conducted in 2013 and test subjects were asked their findings on the VR system in a interview. It is a pity that very few real patients could test the prototype, but some positive and negative aspects came up during the test. These aspects are listed below:

- Children were very enthusiastic about the experience with the VR system;
- The hygiene of the VR system could be improved. The cleaning of the VR system should be easier than it is now;
- Calibrating the tracker takes a lot of time and is tiresome;
- The cart where all hardware is stored is very large and difficult to move;
- All connector cables are long enough;
- The cable of the mouse is too short;
- The fact the VR system can be turned on by only two buttons is pleasant. It would be even more pleasant if it could be done with only one button;
- The monitor that stand on the cart is very vulnerable;
- The medical practitioners cannot see what the patient is seeing in de HMD;
- The design of the VR system is outdated and is experienced as rectangular.

2.1.3 EXPERT REVIEW OF OLD VR SYSTEM

At first the idea was to conduct an usability test at UZ Leuven with the old VR system. Unluckily it appeared very difficult to realize this. Treatment of burns is not planned in advance and also the patients are not willing to cooperate with such a test. This is mainly because the treatment of burns is very painful and patients do not like it when there are more people involved during this treatment other than de medical practitioners. Therefore the decision is made to conduct expert reviews with the medical practitioners.

The questionnaires that are used during this expert reviews can be found in *appendix C and D*. There were two questionnaires: one for medical practitioners that had worked with the VR system or an older version of the VR system and one for medical practitioners that had never used the VR system.

Via Skype an interview is held with the two medical practitioners, the head nurse and the kinestesist, of the medical staff from the burn treatment centre in UZ Leuven concerning the burn treatment of children. The interview provided important information about the procedure during the treatment and information about the hygiene regulations. The outcome of this interview is incorporated in this report. The complete interview can be found in *appendix D*.

2.1.4 CONCLUSION OF ANALYIS OF OLD VR SYSTEM

The review of the old VR system showed that there is room for improvement. The UZ Leuven has tested the old VR system but unfortunately not many test subjects with actual burns have used the VR system. Nevertheless a few good points of improvement have been identified. The cart with all the hardware was too large for easy movement and the practitioners really want to see what the patients in seeing through the HMD. Also the disinfection and cleaning of the device has to be made a lot easier.

Is was a pity that there could be no real contact with the user of the product, maybe some other improvements could be identified if a real interview was conducted. However the most important aspects are discussed via Skype and those have given a good overview of the problems with the old VR system and wishes for the new VR system.

2.2 SURROUNDINGS AND USERS

2.2.1 SURROUNDING ANALYSIS

Hygiene guidelines
All materials that are used in a hospital must satisfy certain hygiene protocols. For hospitals in the Netherlands the government provides guidelines that need to be enacted. These guidelines are made in a workgroup: Werkgroep Infectiepreventie (WIP).

This group states that surfaces, furniture or objects in a treatment room needs to be disinfected when they have been in contact with blood or other bodily fluids. Disinfection then takes two steps:

1. First, the contaminated spot needs to be cleaned by means of collecting the fluid with a tissue. Gloves need to be worn during this procedure.
2. Secondly, after removing the fluid, the cleaned spot needs to be disinfected with chlorine (1000 ppm) or with ethanol (70%).

Chlorine is a commonly used disinfectant because it has a broad spectrum, it is cheap and it works rather quick. The substance does have some corrosive properties whereby some metals cannot be disinfected with chlorine. Chlorine (1000ppm) kills the following threads:

1. Vegetative bacteria (good)
2. Bacterial spores (slow)
3. Mycobacteria (good)
4. Lipophilic viruses (good)
5. Hydrophilic viruses (good)
6. Fungi (slow)
7. Yeasts (good)

A possible danger with the use of chlorine is the emergence of chlorine gas (for example when there is a increased temperature). It is also important to remove the residue after disinfecting the contaminated spot by rinsing the surface, otherwise there is a chance that toxic waste remains.

Alcohol has always played a big role in disinfection in hospitals. It is a reliable substance and it can also be used on human skin. It is unsuitable for use on large surfaces and it cannot be used as a spray. This is because the alcohol is too volatile and too flammable. Ethanol (70%) kills the following:

1. Vegetative bacteria (good)
2. Mycobacteria (good)
3. Lipophilic viruses (good)
4. Hydrophilic viruses (good)
5. Fungi (good)
6. Yeasts (good)

Some materials do react with ethanol. Some synthetic materials (for instance polyethylene) harden when they are exposed to ethanol for a long time. It is also possible that alcohol absorbs particular substances out of rubber that could cause mucosal irritations. Alcohol is one of the few disinfectants that leaves no residue. It is not necessary to rinse a surface after disinfecting it with alcohol.

The materials that are used in the controller have to be resistant to these substances. If it is possible the design of the controller should contain as little joints or edges as possible to enable easy cleaning.

Burn treatment

The burn treatment where VR technology is going to be used is the cleaning of the wounds and the replacement of the bandages. In the UZ Leuven this can happen in two rooms an intensive care treatment room or an wet room (mainly used for easy cleaning of the wounds). The intensive care treatment room is also the room where the patient sleeps during hospitalization. The bed that is used in this room is shown in *figure 2.2* and more details about the dimensions of the bed can be found in *table 2.2*.

2

Table 2.2 | Dimensions of hospital bed that is used in treatment room of UZ Leuven.

Entity of bed	Dimensions (in mm)
Width	890
Length of adjustable safety rail	1600
Diameter of rail on backend	330

Figure 2.2 | Hospital beds that are used in the treatment rooms of UZ Leuven.

The treatment of cleaning or replacing the bandages takes from 20 minutes to half an hour. In the paragraph below provides more insight on the treatment by describing it by means of a scenario. This scenario is written on the basis of conversations with the nursing staff of UZ Leuven.

Figure 2.3 | Photos taken during treatment of burns at the Maasland hospital in Rotterdam

Scenario of burn treatment

In this scenario a treatment is described with the use of the old prototype. See *paragraph 2.1.1* for a more detailed overview of the old prototype.

Sam is an eleven year-old boy who had an unfortunate accident with a cup of hot tea. He is currently hospitalized in Leuven in the burn treatment centre. He has been here for two weeks now and the main part of his treatment is successfully completed. He has to stay another two weeks in the hospital so his wounds can heal nicely.

Every two days his bandages need to be replaced and today Frank of the nursing staff is going to carry out this task. Changing the bandages is a very painful experience for the patient. Luckily Sam qualifies for using the VR system during his treatment. With the use of the VR system Sam will experience less pain and the treatment is less annoying.

Sam's bed doesn't have to be transported to the treatment room because the treatment can take place in the intensive care room where he is staying over. Here a staff of three persons will perform the treatment of the burns with the VR system: the head of the nursing staff to perform the actual changing of the bandages and the cleaning, a nurse who keeps track of the pain level of the patient also giving him painkillers if necessary and a third person who is in charge of the VR system.

Besides the VR system also medication is used to reduce the pain of the patient. This is managed by a nurse who stands on one side of the bed. The global location of the staff during the treatment is shown in figure 2.4*.*

All the equipment that is necessary for the treatment is prepared and the head of the nursing staff makes a small talk with Sam to discuss what he is going to do during this treatment, meanwhile the operator collects the VR system from the storage location outside the treatment room. The head of the nursing staff and the other nurse leave the room to put on sterile gloves, a mouth mask and a medical apron. In the meantime the operator of the VR system brings in the VR system and since Sam has used the VR system for multiple times now, he is familiar with the procedure. While the operator puts the HMD on the head of Sam, the nurses return.

Sam can start playing the VR game and the nurses can begin with the treatment. The operator keeps track of Sam playing the game. When the game is too difficult or too easy the operator can adjust the amount of enemies or speed up the game. The head of the nursing staff is busy changing the bandages of the patient whilst the other nurse focuses on the pain the patient is experiencing and if necessary gives the patient some painkillers.

After the treatment the operator removes the HMD and transports the VR system back to the storage room. The VR system will be cleaned in the storage room. The two nurses clean up all the other equipment that was needed for the treatment and Sam can rest.

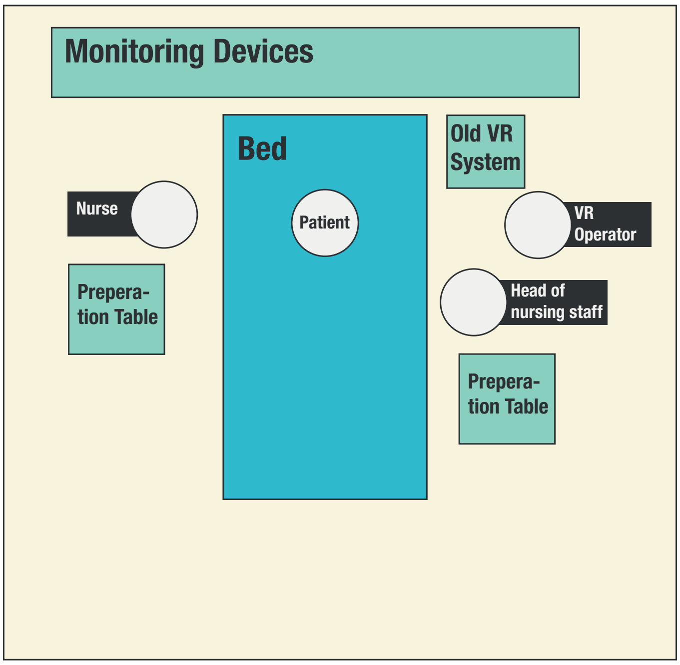

Figure 2.4 | Overview of treatment room

Looks and feel of medical equipment
The looks and feel of the new controller are of great importance, therefore requirements will be set about the look of the new product. Within this assignment two aspects about the aesthetics of the product will be investigated:

1. Affiliation within the setting of hospitals. The product will have to be trusted by the patients and the medical practitioners. This can be achieved by making sure the design of the new product is in line with the current market of medical equipment.
2. Affiliation with the corporate identity of Cinoptics. The new VR system will be the first product of Cinoptics and that is why it is important that the new product will express the new vision and corporate identity of Cinoptics.

To fulfill these two requirements an analysis is made of the design of medical equipment nowadays and in *paragraph 1.1.2* and *appendix H* there is an report on the creation of the new corporate identity and vision of Cinoptics.

In order to map the new trends of medical equipment a product collage is made (*figure 2.5*). This collage contains products that have a lateral connection with the product function of the controller. The most important goal of the product collage is to extract some style characteristics that can be used in future design of the controller.

Figure 2.5 | Product collage

Reliable
All product in the collage express a certain feeling of reliability. They all look trustworthy, strong and at first glance it looks like they could handle a few knocks and bumps. Reliability is of course of utmost importance in the medical world. When a patient does not trust the equipment that is used for his treatment it can lead to discomfort and fear. Both factors do not contribute to the immersive feeling that is tried to reach.

White with a colour accent
Notable is that all product have a white or a light grey colour, almost no exceptions are found. White is naturally a colour that represents clean and purity which is a good fit for a medical surrounding. Modern medical equipment tends to use one accent colour more often than before. Mostly these accent colours are bluish or greenish.

Round shapes
There is a clear shift from rectangular design to round design. Former medical equipment was a lot more technical and rectangular than nowadays. The current medical equipment has almost every corner rounded.

Nice and soft
Because all these round shapes all the medical equipment has become less 'harsh'. Former medical equipment had a clear technical aspect, many cables and knobs were visible. Nowadays all these technical aspects are hidden within the product. This is why all the equipment looks more friendly and expresses a softer feeling.

2.2.2 STAKEHOLDER ANALYSIS

To get a better view of all interest that play a role during the HBK-project a stakeholder analysis has been made. Every stakeholder that has an interest in this project is listed below:

1. **Client**: Cybermind Interactive Nederland/Cinoptics
2. **Financier**: Stichting Help Brandwonden Kids
3. **Hospital**: UZ Leuven, UZ Gent and the Martini Ziekenhuis
4. **Medical practitioners**: doctors and nurses within the hospitals listed above
5. **Patient**: Children with burns in the age of eight to sixteen

2

In the paragraphs down below every stakeholder will be reviewed and there interest will be listed. An overview of all interests can be found in *table 2.3*.

Table 2.3 | Overview of the interests of all stakeholders

Stakeholder	Interest(s)
Client	
Cybermind Interactive Nederland/ Cinoptics	▪ Make a good starting point for new product line ▪ Enlarge demand for VR systems ▪ Convince other hospitals of the success of analgesia using VR systems
Financier	
Stichting Help Brandwonden Kids	▪ Help children with burns during burn treatment and afterwards ▪ Minimize the costs
Hospital	
UZ Leuven	▪ Reduce pain during treatment for burn patients ▪ Investigate effects of VR system on pain analgesia
UZ Gent	▪ Reduce pain during treatment for burn patients ▪ Perform academic research and publish medical publication
Martini Ziekenhuis	▪ Reduce pain during treatment for burn patients ▪ Set up large research to investigate effects of VR system on pain analgesia alongside with a clinical psychological research
Medical practitioners	▪ Being able to do their job more securely ▪ Easy to use product
Patient	▪ Experience less pain during treatment ▪ Experience immersion

Client

Cybermind Interactive Nederland/Cinoptics

During the project Cybermind changed its company name. The product that is developed during this assignment will be fall under the newest and also first product line of Cinoptics. Therefore it is important that this product is of high quality to show the market what Cinoptics can do. This product will be the starting point of the new company name

Research that studies analgesia using virtual reality started only a few years ago. A lot of research has to be done before that fact is proven that virtual reality can help in pain reduction. Until now the results are quite positive en more and more studies show the same results. Studies prove that on average a reduction of pain of 40% can be achieved using a VR system. Many hospitals all over the world show their interest in this type of treatment and the demand for VR systems is rising. This demand is very prosperous for Cinoptics and they want to enlarge this demand in order to let their company grow.

Supplying the hospitals that take part in de HBK project with VR systems will hopefully convince other hospital in this region to look into VR analgesia.

Financier

Stichting Help Brandwonden Kids (HBK)

This foundation is founded by victims of burns and has the goal of helping children with burns by financial means. The foundation raises money from various sponsors from organizations, companies, members, honorary members and gifts. These parties al want that child patients with burns get as much help as possible during their treatment. A way of helping is reducing the pain during these treatments and this can be achieved by using VR systems.

Obviously the financial resources of HBK are limited. Therefore the new VR system should not be too expensive and an eye must be kept at the price tag of the prototype. Also the hospitals will lose interest if the VR system becomes too expensive.

Hospitals

UZ Leuven

The hospital of Leuven already tested the first prototype from Cybermind in 2012 and has executed a few test with this prototype. A handful of therapists and practitioners are instructed by Cybermind so they could use the VR system. They tested the system mainly on 'non-patients' because is appeared very hard to find burn patients that were suitable for using the prototype mostly because of design flaws in the prototype. UZ Leuven is very eager to try out the new prototype of the VR system and in order to help their patients and study the effects of the VR system on pain analgesia.

UZ Gent

The hospital of Gent did not get their hands on the first prototype but has heard of the project trough contact with the UZ Leuven. They were impressed by the results and they are making plans to use VR systems for pain analgesia. Not only do they want it to use it for treatment of burns but also for various other painful treatments. They are also interested in academic research with the VR system what could lead to an medical publication.

Martini Ziekenhuis

The Martini Ziekenhuis has worked with even older version of the VR system in combination with similar game developed in the United States. After a long period of radio silence the Martini Ziekenhuis has shown interest again in using the VR system on the burn centre. This would be accompanied by a clinical psychological research.

Medical practitioners

Research has shown that by making use of the VR system patients are more relaxed and this means that patients can be easier treated for the burns. Without the VR system patients can sometimes be restless because they experience more pain. With the VR system medical practitioners have a better chance of finishing their job more securely.

The medical practitioners will also want an product that is easy to use. For the medical practitioners, especially those in UZ Leuven, it is important that the product will be a better version than the prototype that is being used right now.

Patients

The patients most important interest is that feel as less pain as possible. Therefore the VR system must created a total immersive experience.

2.2.3 USER ANALYSIS

The user analysis is based upon different interviews and questionnaires which are held during the project. Unfortunately there was no possibility to get in contact with the patients and their analysis is based on findings in literature.

Primary target group

Head of the nursing staff

Three persons of the nursing staff are involved during the treatment of the burns. The most important person is the head of the nursing staff who performs the actual treatment. During the treatment he stands on the right or left side of the bed, depending where the burns are located. During the treatment he does not come in contact with the controller or the HMD. This is because of two reasons. Firstly, the practitioner needs to concentrate on the treatment of the burns and all distractions could lead to little mistakes which are annoying to the patient. Secondly, the hands of the practitioner are sterile, which allow him to treat the burn. If he would operate the controller than each time this happens he would have to clean his hands or he had to changes his gloves.

The biggest concern of the head of the nursing staff is that the controller may not impede his activities, the design of the controller should try to achieve this. The other big improvement of the controller, or rather the VR system as a whole, would be the distraction of the patient. Hereby the patient is calmer and the practitioner can perform his treatment better that before.

Nursing staff

The second person that is present during the treatment is a nurse that controls the painkillers. For many of the treatments, patients get painkillers to ease the treatment. The nurse doses these painkillers and during the treatment the dose can vary. Furthermore the nurse has no contact with VR system and she has the same concerns and advantages as the head of the nursing staff.

Operator

The third person is the operator of the VR system. He has the most interaction with the controller. The operator will get the controller out of the storage room and will install the it in the treatment room. He will not only install the controller but also set up de HMD and help the patient with adjusting the HMD. During the treatment the task of the operator is solely to operate the VR system and adjust the game to the needs of the patient. Therefore he needs to be able to constantly see the tablet where the game is running, here he can see if the game is adjusted too easy or too hard.

The operator is a member of the nursing staff who has followed an extra instruction on how to use the VR system and therefore is not schooled differently than the other nurses (except for the extra instruction). In the future it will be possible that only two people will conduct the treatment. The nurse that controls the painkillers will then also control the VR system. It is therefore important to see if it is possible that the casing fits in both the situations (treatment by three people and two people).

Secundary target group

Children

The VR system that is designed is intended to be used by child patients in the age of 8 till 16. The patients will not get in direct contact with the controller, only the HMD will have an interaction with the child. The child only sees the controller, but the controller is the first acquaintance with the VR system. That is why the first impression with the VR system (c.q. the controller) should be a happy one. Children at a very young age might not directly understand the purpose and meaning of the VR system and could experience fearful thoughts about the it.

Therefore it is important that the aesthetics of the product look friendly, simple and intuitive. This friendly more childish appearance may not prevail in the design of the product, it also has to connect with the medical surroundings it will be used in. A combination between these two appearances has to be found.

Children with burns
Children with burns are often traumatized and their mental trauma should be taken into account. The child friendly design is even more important with traumatized children because their anxiety level can be even higher because of the pain they experience from burn treatment.

2.2.4 CONCLUSION OF USER AND SURROUNDING ANALYIS

The treatment procedure of burns and the hygiene guidelines in hospitals are mapped and important results were that the product must be resistant to ethanol (70%) and preferably chlorine. It is also desirable to look if the casing can be used when instead of three two people are performing the treatment.

The medical practitioners are the most important stakeholders when we consider the design of the casing. Their demands and wishes must be met in order to make a successful product. Therefore the casing should offer a practical and functional solution, it should take less time to install than the previous prototype and it should not block the practitioners while treating the patient.

UZ Leuven is the first hospital that will use this product and therefore specific design choices can be made focused on the UZ Leuven. If possible the two other hospitals (UZ Gent and Martini Hospital) can be taken into account.

The design and styling of the product should correspond with the design of modern medical products and if possible should contain a child friendly look and feel. Because the product will be developed with the new branding of Cybermind, the product should connect with the corporate identity of Cinoptics. If desirable a brochure can be made to display the new product (possibly with the HMD) for interested clients and hospitals.

2.3 DESCRIPTION OF THE NEW PRODUCT

2.3.1 DESCRIPTION OF COMPONENTS

The hardware specifications of the VR system were already know before this assignment started. *In appendix I* an overview of all components and there connections is shown. This is done for the three main components of the VR system: the HMD, the controller and connector cable. A detailed description of al main components and specific parts can be found further in this paragraph. The part of the controller are described most detailed, this because in this assignment a design for the controller will be made.

As can be seen in *Appendix I* there are three main components in the VR system:

1. **Casing of the head mounted display (HMD).** This is the headset the patient will be wearing while playing the serious game.
2. **Casing of the controller.** In the controller all hardware is present in order to control the HMD. The controller will make the VR system an all in one solution in which, probably, the HMD can be stored. During the treatment the medical practitioner can watch the images on the tablet which tell him what the patient is seeing at that moment and here he can change some game setting.
3. **Connector cable.** This is cable that is running between the controller and the HMD. All the information as well as the power supply goes through this cable.

2

HMD
Optics – These are the lens modules that are in front of the patient's eyes. The optics will make sure that the light that is emitted by the displays will be correctly guided to the patient's eye. Only if this is adjusted in the right way the patient will experience immersion.

IPD mechanism – With this mechanism it is possible to change the interpupillary distance (IPD). The IPD is the distance between the pupils of the patients. This needs to align with the optics in order to create a good image.

Focal length mechanism – This mechanism changes the dioptre of the lens system so people with eye defects can still use the VR system.

Displays – When the patient is wearing the HMD he is looking (indirectly) to the displays. The displays will be controlled by the controller. The energy needed to run the displays comes from the battery inside the controller. Via various electronics the displays are powered. There are two displays, one for the right eye and one for the left eye. Both displays need to be controlled separately.

Electronics - In the HMD a lot of printed electronic circuit board (PCB's) take care of guiding data to the correct location. The power supply divides the power between the different components (speaker, displays, etc.). The VCU en DCU are both decoders which translate the data they get form the tablet and make it ready to display it at the two displays.

Motion tracker – This device tracks the motion of the patients head. Is has 6 degree's of freedom so every possible move can be tracked. The motion tracker sends his data to the tablet which converts the translation of the tracker to movement of the point of view in the game.

Speakers – Provide the audio for the game. They are indirectly connected to the tablet.

Casing
Power switch - Switch to turn on of turn off the VR system.

Tablet – The heart of the VR system, from this device every other electronic device is controlled. The tablet has its own battery. The tablet that will be used for the controller is a Microsoft Surface 2 Pro (as shown in *figure 2.7 and 2.8*). A list with all the relevant specifications can be found in *table 2.4*.

Table 2.4 | Specifications of Microsoft Surface 2 Pro

Outside	
Dimensions *(mm)*	274 x 173 x 14
Weight *(grams)*	907
Casing material	VaporMG
Physical buttons	Volume button, on/off button
Screen	
Mates *(inch)*	10,6 (Full HD screen)
Resolution *(px)*	1920 x 1080
Multi-touch	Yes (10-point multi touch)
CPU & wireless	
CPU	4^{th} generation Intel Core I5
Internet	Wi-Fi
Bluetooth	Bluetooth 4.0
Battery	
Stand-by time	7-15 days
Charge time	2-4 hours
Runtime with game	1,5 hour
Camera, video & audio	
Camera	Two 720 HD camera’s (front and back)
Audio	Stereo speakers, microphone
Connections	
USB	USB 3.0
Memorycard	microSDXC-card reader
Audio	Headset connection
Video	Mini-DisplayPort
Other	Coverport
Sensors	Surroundinglight sensor, accelerometer, gyroscope, magnetometer
Other	Surface-Pen included

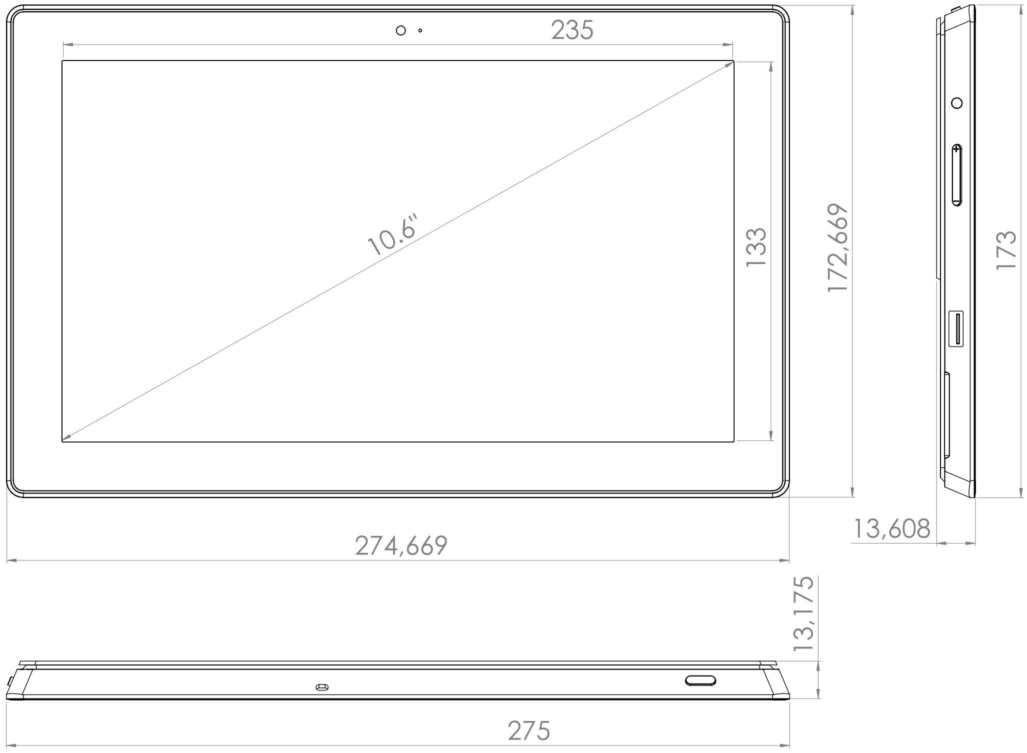

Figure 2.7 | Dimensions of the Microsoft Surface 2 Pro

Figure 2.8 | Microsoft Surface 2 Pro

Splitter- This component splits a single display signal into two signal. Because the HMD has two displays, it needs two separate video signals. The splitter that is used in the controller is the Lenovo DisplayPort to Dual-DisplayPort Adapter. It contains one input for a DisplayPort connector and two outputs (also DisplayPort Connectors).

Table 2.5 | Specifications of Lenovo DisplayPort to Dual-DisplayPort Adapter

Global dimensions	60 x 90 x 20
Inputs	1x DisplayPort
Output	2x Displayport

Figure 2.9 | Lenovo DisplayPort to Dual-DisplayPort Adapter

Cable combiner – The cable combiner is a box that combines multiple generic interfaces for transport over one single cable. So all the output from the controller goes through this combiner so it can be transported easily over one cable to the HMD. It contains input for power, USB and a dual DisplayPort connector. The output of the cable combiner is a dual DisplayPort. In essence the cable combiner adds electrical power and a USB signal to the dual DisplayPort.

Table 2.6 | Specification cable combiner

Global dimensions	50 x 30 x 10 mm
Inputs	1x Electrical power
	1x USB
	2x DisplayPort
Output	2x Displayport

Proposal for changes to hardware

The old VR system had no battery and needed a power outlet in every situation. Regulations about the use of power outlets in the treatment rooms of hospitals are strict. An isolation transformer needs to be added to secure the patients safety and prevent potential shocks from the power outlet.

In consultation with Cybermind the decision is made to make the VR system work wireless. This would allow to make the controller even smaller and a lot easier to set up. There are also no cables leading away from the bed where people could fall over.

A solution needed to be found that could be used as a battery for the OLED displays inside the HMD and as a backup for the tablet. The power for the OLED display is transported over USB as well as for the tablet. The most practical solution was to embed a USB power bank in the design. The 'A-Solar Xtorm AL360 Power Bank 11000 mAh' seemed to a perfect solution. The two USB ports could power both the tablet and the OLED displays and the large capacity ensure that the VR system can operator for quite some time.

Table 2.7 | Specifications A-Solar Xtorm AL360 Power Bank

Global dimensions	120 x 80 x 25 mm
Inputs	1x Electrical power (USB micro)
Output	1x USB (1 A) 1x USB (2.1 A)
Capaciteit	11000 mAh

Figure 2.10 | A-Solar Xtorm AL360 Power Bank

2.3.2 FUNCTION OVERVIEW

The casing has a certain amount of functions it has to fulfil. All these functions are extracted from the research that has been done in *chapter 1 and 2*. The functions are listed below:

- The casing controls the display of the HMD
- The casing controls the audio of the HMD
- The casing communicates with the tracker on the HMD
- The casing supplies power to all electronic components
- The casing runs the software necessary to play the game
- The casing stores the HMD, cables and clicker.
- The casing is portable
- The tablet can be docked in the casing
- The casing can be placed on a surface and/or can be hung onto the bed

2.3.3 USER-PRODUCT INTERACTIONS WITH CONTROLLER

The practitioner has a certain interaction with the controller. From the scenario of *paragraph 2.2.1* a list of interactions can be identified (see *table 2.8*). A short description is given of the interaction in chronological order therefore the scenario is used as guidance.

First the VR system needs to be transported to the treatment room. Therefore the practitioner needs to be able to carry the controller, containing the HMD. The total VR system cannot be too heavy and needs to be easy to grasp.

Then the practitioner needs to place/hang the prototype somewhere in the treatment room. It must be immediately clear how the controller can be placed. The feeling of this placement is also important, the practitioner must immediately feel that the controller stand or hangs stable.

Next up is the connecting of the cables en preparing the VR system to use during the treatment. All cables (one or two) need to be connected. The connector should fit very easily and the cables should have enough length to reach form the controller to the HMD.

When everything is set up, the practitioner helps the patient with putting on the HMD. The HMD as well as the cables are stored in the controller. It must be very easy to get the cables and HMD in and out of the controller. The last thing that needs to be done is giving the patient the clicker, which is used for interacting with the game. After the patient is ready to play the VR game the practitioner needs to start the game. By pushing a button (or maybe two: one for the controller and one for the HMD) the VR system is started.

The start-up time of the total system needs to be as short as possible in order to continue with the treatment right away. During the treatment the practitioner must be able to look on the tablet of the controller. Here he can see the image that the patient can see on the HMD. Also the practitioner can change some of the game settings on this tablet. So he needs be able to reach and see the tablet that is connected op de tablet.

Table 2.8 | Overview of user-product interactions and requirements

User-product interaction	Requirements and whishes for controller
Transport of VR system	■ not too heavy ■ easy to grasp ■ requires only one hand to carry
Setting up the VR system	■ intuitive placement of controller ■ evoking the feeling of reliability (e.g. stability when standing or hanging
Unpacking or packing VR system	■ easy access to cables and HMD ■ evoking the feeling of reliability
Connecting cables	■ evoking the feeling of reliability (e.g. cables are securely connected and cannot fall out) ■ cables are long enough ■ clarification of how the cables can fit in the sockets
Place the HMD on patient	*Not applicable*
Handing the clicker to patient	*Not applicable*
Starting and turning off VR system	■ as little action required as possible
Interacting with tablet	■ easy access to tablet ■ good viewing angle
Cleaning of controller and clicker	■ no edges where filth can pile up ■ material is suited for cleaning

After the treatment is done, the system can be turned off and the HMD can be removed from the head of the patient. The cables can be disconnected and after the HMD has been cleaned it can placed back in the controller together with the cables. The controller and clicker also needs to be cleaned. The clicker can be stored in the controller and after that the VR system is ready to be transported.

2.3.4 CONCLUSION OF ANALYSIS OF THE NEW PRODUCT

All the parts that will be in de casing are defined and specifications and dimensions are known. All connections between these components are mapped in order to fully understand the operations of the product. The connections between the components can be of importance in the placing of the components in the casing.

All the research resulted in an overview of functions that the casing needs to fulfil. These will led to an number of requirements for the design of the casing. Also the interaction that the product has with is user has resulted in an overview of requirements and wishes for the design.

2.4 REQUIREMENTS AND WISHES

2.4.1 LIST OF ALL REQUIREMENTS AND WISHES

Requirement

After all research that was done in preparation of this assignment a list was made that listed all requirements and wishes for the controller. The list is separated in different sections, each section consists of another category. The requirements are ranked according to their level of importance on a scale from 1 to 5 where 1 stands for least important and 5 stands for most important. This scale is added so the concepts that are generated could be ranked more precisely.

2

Table 2.9 | Overview of requirements with importance ranking

REQUIREMENTS	IMPORTANCE
Aesthetics	
The controller must connect with the corporate identity of Cinoptics	4
The controller contains a simplistic design with minimal distracting features	4
The controller must connect with the appearance of modern medical equipment	3
The controller must evoke the feeling of a sterile environment to the patient	3
Geometry	
The controller may not block the view of the medical practitioner	5
The controller may not block the proceedings of the medical practitioner	5
The controller is suitable for transport by hand by one person	4
The controller can be transported through the hospital	5
Performance	
The VR system can run for 30 minutes on one battery	3
The controller weighs less than 1 kilograms (without peripherals)	3
The controller can store the HMD and the connector cable	2
The controller can dock the tablet that is used to control the game	5
The controller supplies power for the HMD and the tablet	5
The controller can be carried using one hand	2
The VR system can be set up in 5 minutes	4
Physical	
The material of the controller is resistant to 70% ethanol an chlorine	5
The controller does not have small grooves or other small spaces where filth can add up	4
The controller can be easily cleaned by medical personnel	4
The casing of the controller may not be warmer than 50 °C	4
The controller prevents all electronic components from overheating	4
The controller can contain all electronic components and keeps them in place	5
The operator can move the tablet towards or away from himself	2
The use of the controller doesn't require any changes to the treatment room in UZ Leuven	4

Wishes

Also a list of wishes is created. Here product demands that are not of vital importance to the success of the product. Therefore these wishes have an importance of 1 on the importance-scale.

Table 2.10 | Overview of wishes with importance ranking

WISHES	IMPORTANCE
The controller can also be used in UZ Gent and the Martini Hospital	**1**
The controller can be used in the wet environment of the wet treatment room of UZ Leuven	**1**
The operator can communicate with the patient through the controller	**1**
Filth should be visible on the surface of the chosen material	**1**

2.4.2 PRODUCT DESCRIPTION; STARTING POINT FOR THE NEW DESIGN

In order to have a good starting point for the idea phase a global product description is made with some design conditions.

The medical practitioners are the most important user group of the new casing and the design of the new product should ensure that as many of their requirements as possible are met. The three most important requirements are:

1. The product should be more time efficient. Currently the product takes too long to transport and takes too much time to set up.
2. The medical practitioners should be able to view at the screen that shows the images that the patient is seeing at that exact moment. They need to know if the VR system works as desired and if the patient actually experiences immersion.
3. The product should be very easy to clean and disinfected if necessary.

Furthermore the product creates a feeling of unity. The medical practitioners will no longer see six or seven different hardware components that together form the VR system. There will be only the HMD, the casing and the cable that connect these two products. The casing should therefore aim for a simplistic and intuitive design.

IDEATION

3

The result of the previous chapter, the list of requirements and the product description, will be the starting point of this chapter. All the surroundings of the treatment room and user requirements are clear now and it is time to translate these requirements into practical solutions. To get a better grasp on designing a product that meets all requirements the main design problem (designing a controller) is divided into smaller sub problems.Different solutions for these smaller problems are given.

Another starting point is found by analyzing all the hardware components that will be part of the controller. What casing shapes can be found when placing these components into different set ups.

All these ideas become the starting point for creating the concepts of this assignement. By trying to combine the different ideas concepts will be generated in chapter 4.

3.1 SOLUTION AREAS AND IDEAS

The main design task of this project (designing a casing for the controller) is divided into smaller design problems. In this way more focus can be placed on a single aspect and so a better solutions can be found. Also one solution will not interfere with one another and a more open mindset for finding solutions is created.

The following division is made based on the analysis of *chapter 1 and 2*.

1. Transportability
2. Placing controller near operator
3. Storage of HMD and cables
4. Docking the tablet
5. Heat transfer away from tablet
6. Communications between operator and patient
7. Guidance of cables
8. Starting the controller
9. Colour schemes

These solution areas and the respective solutions will be described in the paragraphs below. In appendix F there is an overview of all the drawings that are made to produce to ideas for all the sub problems.

3.1.1 TRANSPORTABILITY OF CONTROLLER

The controller will not be stored in the treatment room itself but in a storage room of the hospital. Therefore the controller must be transported between these two locations. The transport will take place in house and is performed by one person.

Cart
The whole system could be placed on a cart that contains wheels in order to be rolled around the hospital. The operator would not have to carry much weight and that would minimize the physical load on the operator. This is of importance if the operator needs to carry the controller over a long distance within the hospital. Storage space would also be no problem because there would be enough room for all accessories on the cart.

However, the wheels also give the controller some disadvantages. In the hospital there are quite some cables, especially in the treatment rooms, rolling a cart over these cables sure is not easy. The cart would also cover a large amount of space in the treatment room, a room where there is already little space.

Transport by hand
A solution where the operator carries the controller seems more logical, even more because due to the technological improvements the weight of the hardware is severely reduced in comparison with the old prototype. Therefore the controller, including cables and HMD, could easily be carried by one person.

Adding handles to the design would cause the controller to be easily carried. These handles can be countersunk in the casing of the controller. In this way they would be of no problem when placing the controller on any surface. A combination of the solutions is also possible. A small portable controller which contains wheels and a long handle so it takes the shape of an average trolley.

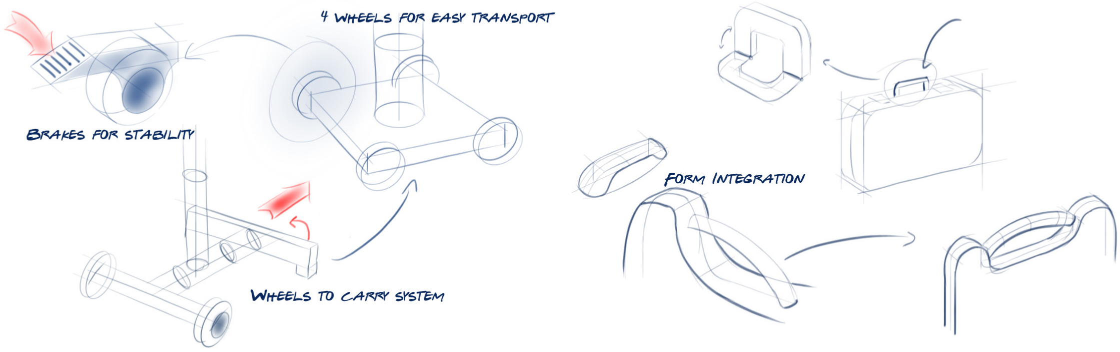

Figure 3.1 | Ideas for transportation

3.1.2 PLACEMENT OF THE CONTROLLER

The controller is to be used in the treatment room of the hospital and needs to get a place in this room during the treatment. Depending on the size and weight of the controller there are several places the controller can be placed. Often medical instruments that contain a display are hanged from the ceiling. Arms with joints make sure the display can be moved and rotated in different positions.

In the treatment room so called preparation tables, or prep tables, are present. These tables serve as side table for multiple purposes. The head of the nursing staff uses the table to store some of the equipment that is needed to perform the treatment. A similar prep table can be used to place the controller on. The most logical location to place the table is at the end of the bed, where the most space is available.

Another option is to hang the controller at the end of the bed. A handlebar is located here and could supply as a mechanism to attach the controller onto. Like said before, at the end of the bed there is a lot of space left for the controller and employees of the hospital agree this is the most logical place to place the controller. Another advantages of placing the casing at the end of the bed is that if the casing could be hanged onto every bedrail with roughly the same dimensions, making is possible to hang the casing at a variety of places.

The last option would be to hang the controller at the wall. A hanging system would need to be designed where the controller could be attached and detached. But the walls are not really near the patient and in this way a great distance is created between the controller and the patient/HMD.

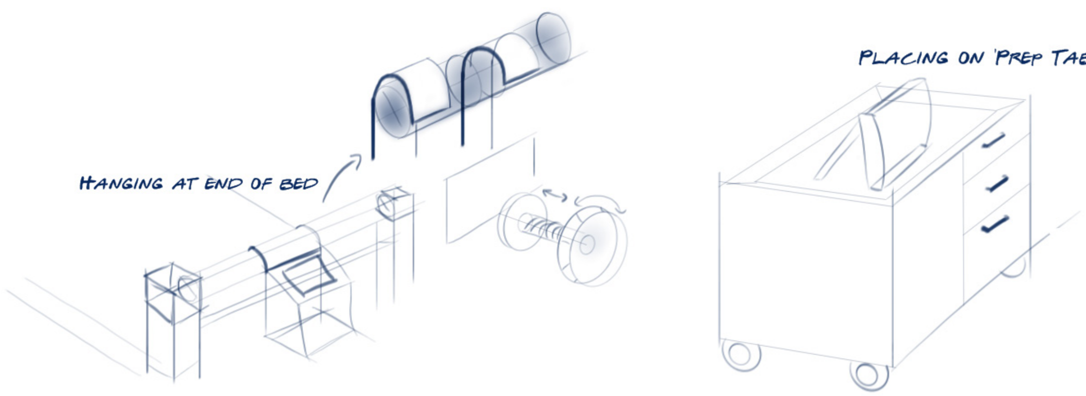

Figure 3.2 | Ideas for placement of the controller

3.1.3 STORAGE OF HMD AND CABLES

The casing needs to be as compact as possible to enable easy transport. The controller is the solution to transporting all the hardware (tablet, splitter, battery) from the storage location to the treatment. When the HMD and the cables can also be transported with the controller an even more compact solution is at hand.

There are different ways to store the cables and HMD in or near the controller. The most simple way is to make some kind of suitcase. For extra protection the HMD (which is rather vulnerable) could be enclosed in an pre cut foam. All shocks are absorbed by this foam and the foam also provides for a clear overview of what is in de suitcase. A bit similar to the suitcase idea is to design a drawer in which all accessories can be stored. Depending on other design choices a choice can be made between those two alternatives.

For easy access the HMD could also be stored in a stand. The centre of gravity of the HMD is in the front end. When this front end is enclosed the rest of the HMD could stick out of controller making it easy to grasp. Problem is that the HMD is much more vulnerable and could easily fall out of the stand when turned upside down.

The cables (and maybe the HMD as well) could be hanged onto a couple of hooks which are fixed on the controller. The same advantages and disadvantages of the stand idea are the case with this idea. It is more vulnerable and it could easily fall of the controller

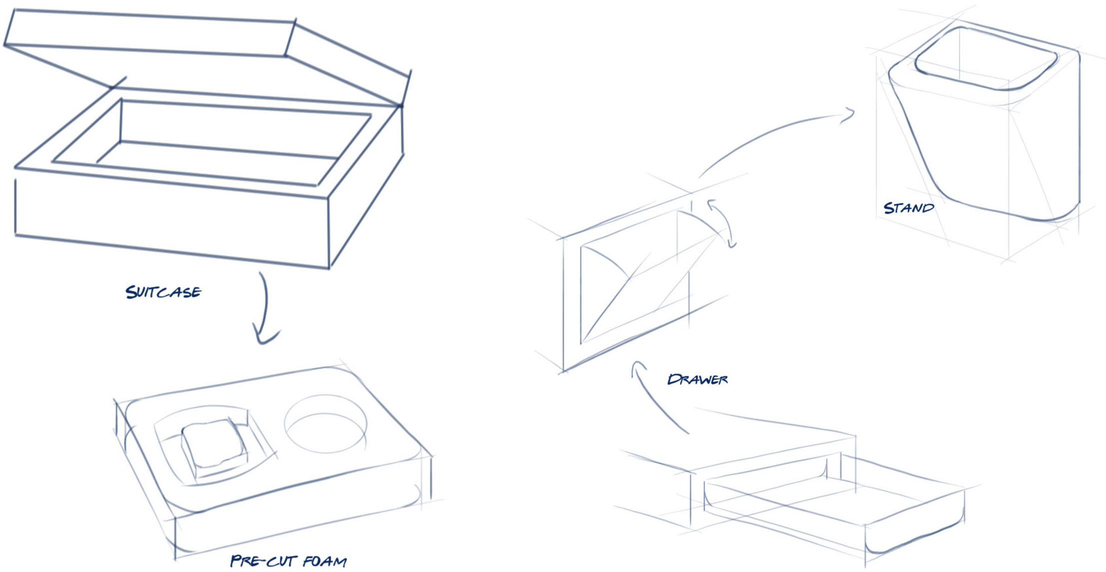

Figure 3.3 | Ideas for storage of the HMD and cable

3.1.4 DOCKING THE TABLET

Because the tablet has connections on each side it is a challenge to make sure the tablet can be docked into and out of the controller. Most tablets have their connectors on one side of the tablet, what makes it easy to design a docking station: you only have to attach the tablet with one side to the docking station.

With the Microsoft Surface 2 Pro you have two sides that must be connected. The docking station of Microsoft itself contains of two gliding sides. When they are clicked into the tablet these gliders keep the tablet in place. This idea could be used for the controller. This gliding principle could be implemented in many different shapes like a suitcase or a drawer. For more stability the tablet can also be laid down instead of standing up. This provides more stability.

Another consideration that needs to be made is whether it is really necessary to dock the tablet. The operator itself does not need to undock the tablet during the treatment and the tablet should only be undocked during service or reparation. Therefore it is also possible to provide a stand where the cables are loose and can be connected before the tablet is placed in the stand/controller.

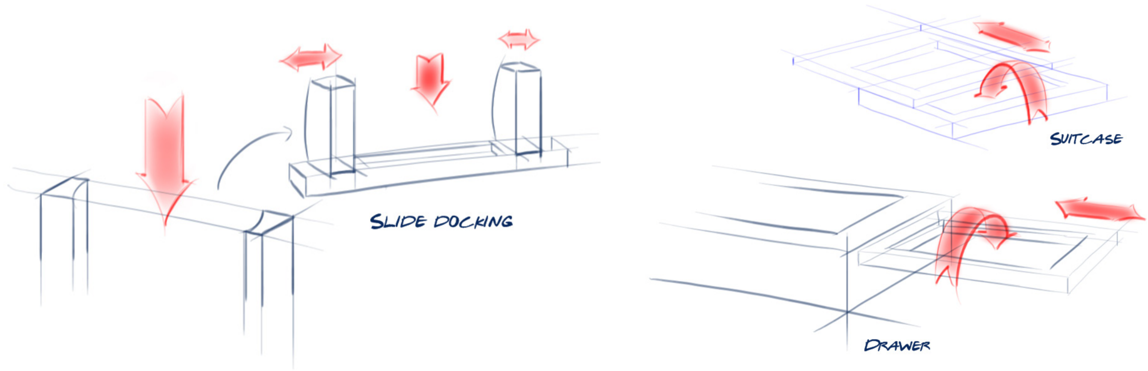

Figure 3.4 | Ideas for docking the tablet in the controller

3

3.1.5 HEAT TRANSFER AWAY FROM TABLET

The tablet that is used in the controller has an active cooling system. Two fans inside the tablet displace the air in and out of the tablet. A cooling grid is placed along the entire length of the tablet, which allows the inlet and outlet of the air. This grid must not be blocked in the controller, otherwise the tablet might overheat. Other than keeping the inlet and outlet of the tablet free there are ways to stimulate the airflow around the tablet.

By placing fans in the controller active cooling can be achieved. A fan that is in connection with the outside of the controller can blow hot air out of the controller. Somewhere else in the controller a passive air inlet needs to be placed in order to suck cold air into the controller. A disadvantage of active cooling is the need for extra electrical energy.

Passive cooling can give another solution. For instance cooling fins can be placed under the tablet to absorb a part of the heat. By increasing the surface area more surface comes in contact with the surrounding air and therefore it can pass more heat on to the air than in the old situation. A drawback is that cooling fins often add a lot of weight to the design. Something you want to prevent in the handheld controller.

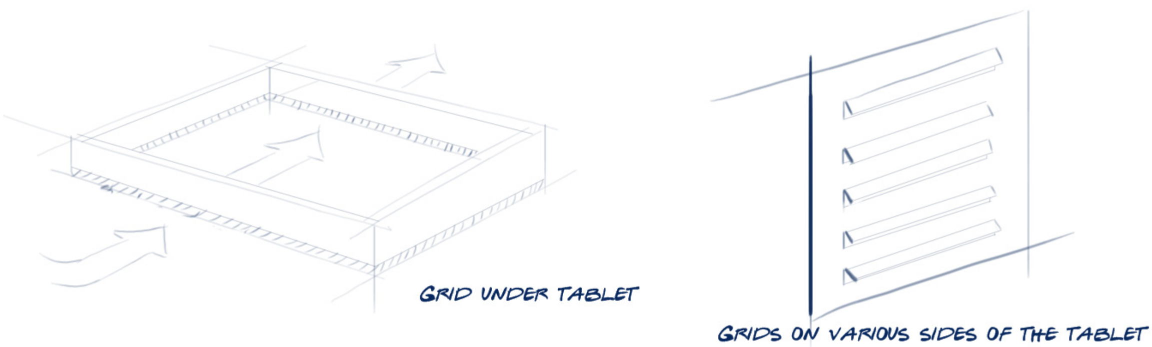

Figure 3.5 | Ideas for docking the tablet in the controller

Making sure the hot air can leave and cool air can enter the controller, can be enough to prevent the tablet from overheating. In other words it might be enough to place enough grids in the controller so air can pass freely from en to the tablet. Research has to show whether the tablet becomes very hot while playing the snowball game. On that basis a decision can be made between passive or active cooling.

3.1.6 COMMUNICATIONS BETWEEN OPERATOR AND PATIENT

During the treatment it is sometimes necessary to talk to the patient. However, when it is not necessary it is always a good idea to not communicate with the patient. Interacting with the patient while he is playing the VR game will result in a loss of immersion, something that is not desirable. In those rare cases that the nursing staff needs to talk to the patient it is often enough to talk loud and clear in order for the patient to understand and hear somebody.

But there are ways to positively influence this communication. A microphone can be added to enable the possibility for the operator to talk to patient. The HMD already contains speakers for playing the music and sound effects during the game.

Another possibility is to add a video camera to the controller. In this way it is possible to video chat with the operator or other people. In a small sub window in the game the patient can see the video chat. However, this is of big influence on the immersion in a negative way.

A more subtle approach is the possibility to type messages that appear in the game. This minimizes the effect on the immersion that the patient is experiencing. The question is whether the patient will notice the messages or that he is too busy with playing the game that the messages do not get any attention.

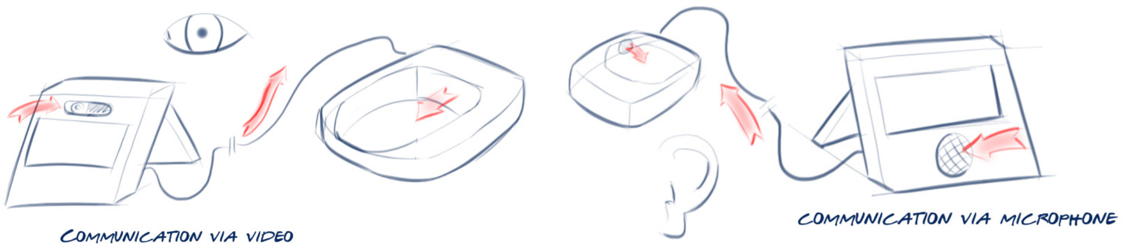

Figure 3.6 | Ideas for communication between patient and practitioner

3.1.7 GUIDANCE OF THE CABLE

No matter where the controller is placed there must be a cable that connects the controller with the HMD. At this moment there is no possibility of transferring the data via a wireless connection to the HMD. This is too unstable and could interrupt the game, what will lead to a loss of immersion. The cable has to run for quite a distance, when the controller is placed at the end of the bed, the cable will be around 3 to 4 meters long. The cable cannot be placed on the ground, because it will become an obstacle for carts and people that need to get around the bed can fall over these cables.

An solution could be to attach snappers to the cable. These snapper could be pressed on the railings alongside the bed. Because the snappers would be closed at the top there is almost no chance that the snapper would slide along the railing. But because they are fixed very tight it can be difficult to attach and detach the snappers.

In order to solve this last problem it is also possible to hang the cable alongside the bed by using hooks. These hooks can be attached and detached more easily than snappers, but slide easier.

The cable can also be guided over the bed instead of under the bed. Many hospital bed already have stands that enable this kind of solutions. A disadvantage would be that the cable can block the practitioner during the treatment. Also the view can be blocked when the practitioner tries to look on other monitors on the other side of the bed.

Figure 3.7 | Ideas for guiding the cable along the hospital bed

3.1.8 STARTING UP THE CONTROLLER

While the HMD has a sensor that detects if the device is placed on someone 's head the controller cannot detect this and does not know when he has got to get out of the stand by modus. There are several possibilities to activate the controller.

Obviously the most simple one is to place a button somewhere on the controller. The only electrical component that needs to be turned on is the tablet. This tablet has a power on button which can be extended to the casing of the controller. To make sure the button isn't pressed by accident, the button can be sunk in the casing.

A more futuristic approach is turning the device on with voice command. This may seem handy but maybe not the most practical solution. When you operate in a noisy area it can be difficult to turn on the controller.

Another option is to activate the controller as soon as the cables of the HMD are connected. The HMD and cables are not connected to the tablet when they are stored. When setting up the complete VR system the controller would automatically turn on and since the software of the tablet is designed to start the game as soon as the tablet goes on, everything is instantly ready to use. When the patient places the HMD on his or her head, he or she can instantaneously use the VR system.

Figure 3.8 | Ideas for starting the VR system

3.1.9 COLOuR SCHEMES

As stated in the analysis in *chapter 2* the look of the product is important because of two reasons: the patient should not be frightened by the looks of the product and the product should fit in de medical environment of a hospital. An important aspect that contributes to the look of the product is the colours that are used. Based on the analysis of different types of medical equipment two colour schemes are created and are shown in *figure 3.9*.

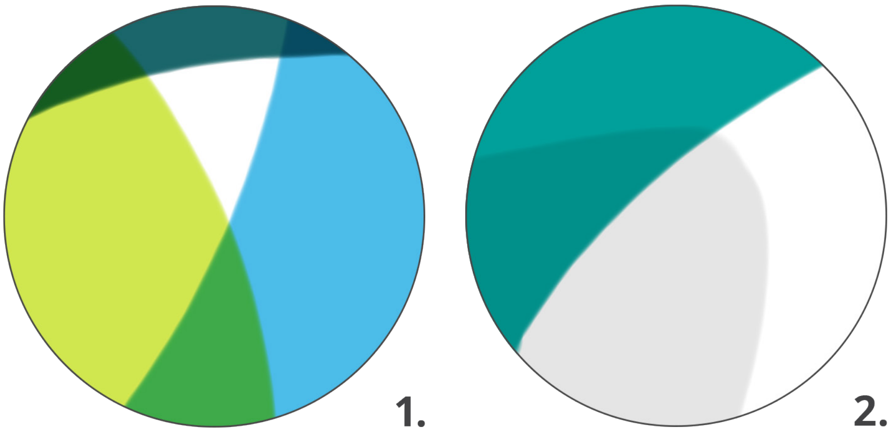

Figure 3.9 | Overview of the two colour schemes

Colour scheme 1 is based on the idea that product should not be frightening too children. Bright and light colours are used. To be sure the product would also connect with the hospital environment colours that are often connected with medical care (green and blue) were used.

The second colour scheme is based upon the new corporate identity of Cinoptics. The green colour is used in the sub brand for the medical branche of Cinoptics. Combining this with more standard colour schemes which often contain a lot of white elements with subtle hints of an accent colour resulted in the second colour scheme.

3.2 PLACEMENT OF HARDWARE COMPONENTS

Dimensions and specifications of all the hardware components are known. Therefore 3D models of the hardware components could be made using Solidworks. By arranging the components in various ways, shapes can arise for the design of the casing.

The four main components (the tablet, the battery, the splitter and the cable combiner) and the cable connecting the HMD and casing were modelled in Solidworks. Also the model of the HMD was used in this analysis. Outlines for the design of the casing were made (shown in *figure 3.10* and *appendix E*). One of the discoveries here was that the HMD was very large in comparison to the other parts.

3.3 IDEATION SKETCHES

The separate idea's now need to be combined into different concepts. In *figure 3.11* and *appendix F* sketches preliminary to the concepts can be found. These sketches try to incorporate the different ideas that are investigated in this chapter. In the next chapter these ideas will be formed into four different concepts.

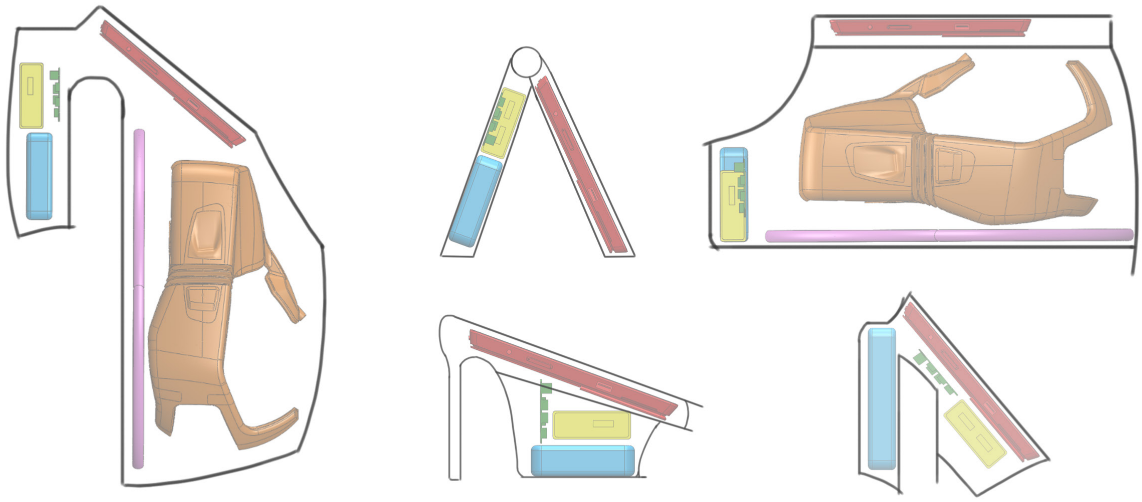

Figure 3.10 | Selection of product outlines using the different arangements of hardware components as a basis

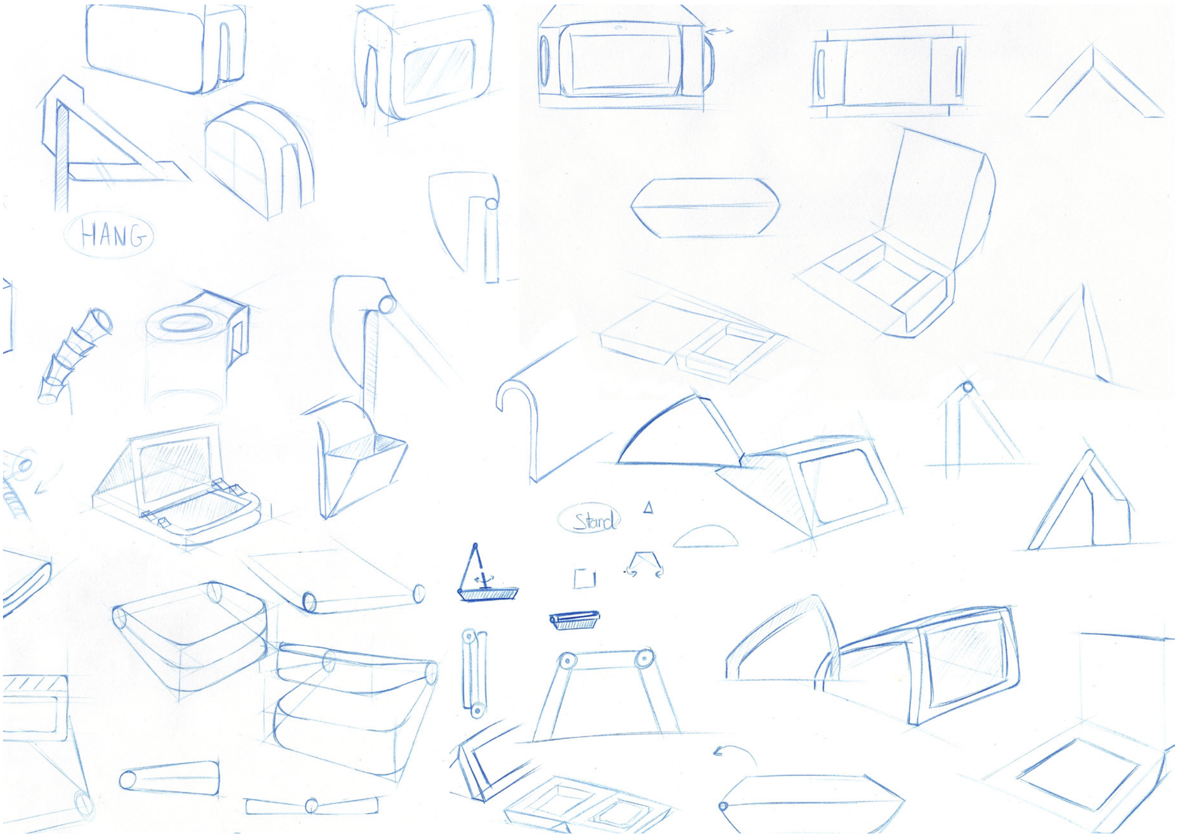

Figure 3.11 | Selection of sketches for casing ideas based upon ideation phase

CONCEPTS

4

In this chapter the main goal will be to translate all ideas from chapter 3 into different concepts so a total solution can will be found. Two methods are used as a starting point for making these concepts. A morphological analyse which selects the most fertile ideas en combine them into a total solution. Secondly embodiment design will use different configuration of hardware components as starting point.

After creating four concepts the program of requirements and the product description of chapter 2 are used to compare all concepts. Together with feedback of the company a selection will be made between the concepts. This selection will function as a starting point for the final concept.

4.1 GENERATING CONCEPTS

Out of the ideas from *chapter 3* concepts were generated. There are many ways and methods do achieve this. Two starting point for generating concepts were used in this assignment: morphological analysis and embodiment design.

4.1.1 HOW TO GENERATE CONCEPTS: MORPHOLOGICAL ANALYSIS

The morphological analysis method sums all the possible solutions for different problem areas. For this analysis seven solution areas from *chapter 3* were used:

1. Transportability of controller
2. Placing controller near operator
3. Storage of HMD and cables
4. Docking the tablet
5. Heat transfer away from tablet
6. Guidance of cables
7. Starting the controller

After selecting the most fertile ideas for each problem area the ideas were placed in a grid, also known as a morphological scheme. This is shown in *figure 4.1*. This scheme is used as starting point for the creation of the concepts. Two of the four concepts were created using this method, the blue and red lines and dots indicate which solutions are chosen for both the concepts. Detailed information about the concepts is given in *paragraph 4.2*.

4.1.2 HOW TO GENERATE CONCEPTS: EMBODIMENT DESIGN

Also the sketches drawn with respect to the hardware components served as a starting point for two concepts. Comparing the different hardware parts made it clear that the cable and HMD would take a lot of space in the total design and, when looking to the dimensions, where out of proportion with the other components. This gave the initiative to also look at concept that would not store the cable and HMD. This gave interesting solutions which were much more compact and therefore much easier to carry.

One of the reasons for the dimensions being out of proportion is that the casing of the HMD and casing of the controller were not designed in relation to each other. Therefore the design of the HMD is far too big for finding a feasible solution that is able to store the HMD and cable.

The embodiment design study resulted in two concepts (concept 3 and 4) who do not provide storage space for the HMD and cable. Configuration and sketches for these concepts can be found in *figure 4.4*.

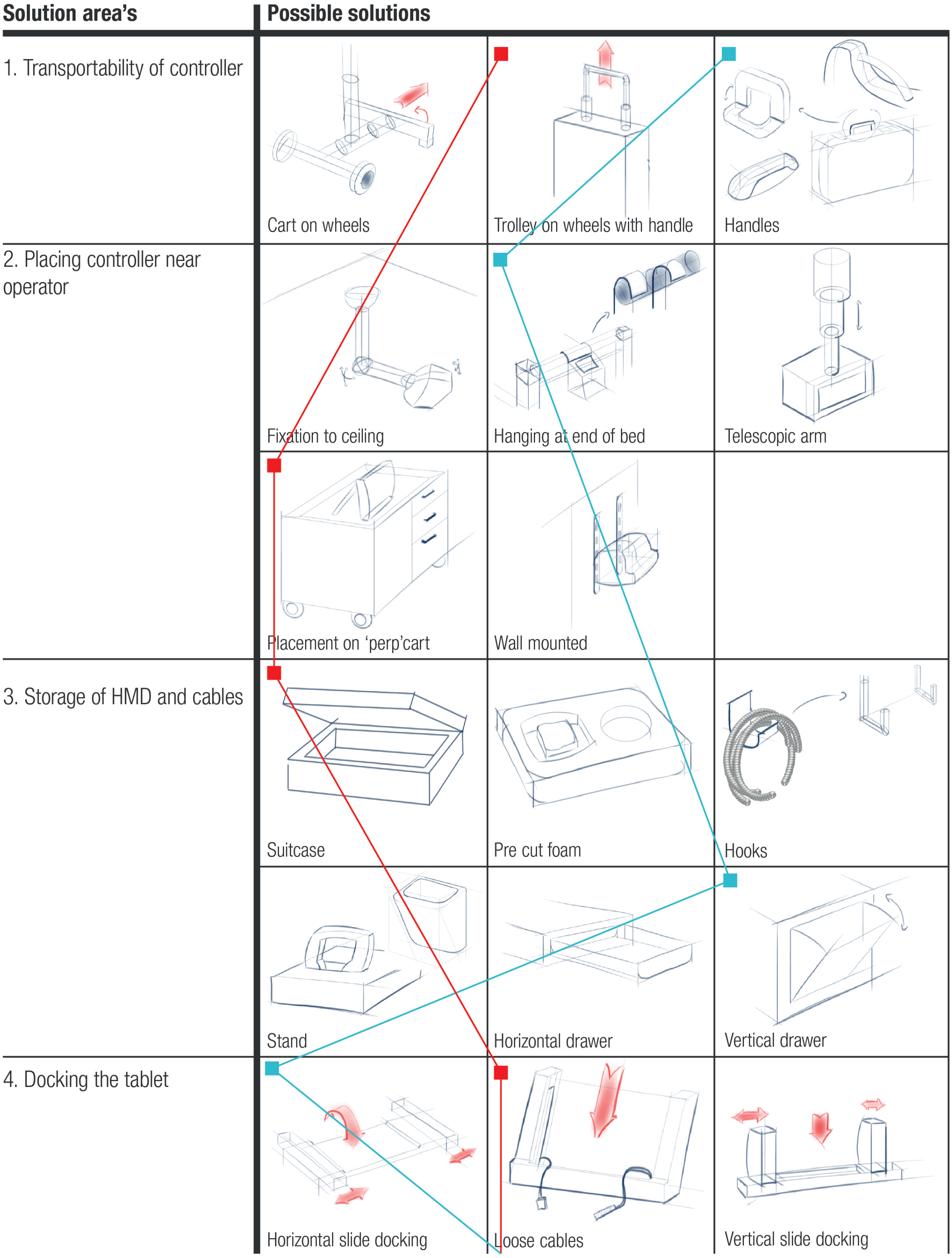

Figure 4.1a | Morphological scheme for generating concepts 1 and 2 *(Continues on the next page)*

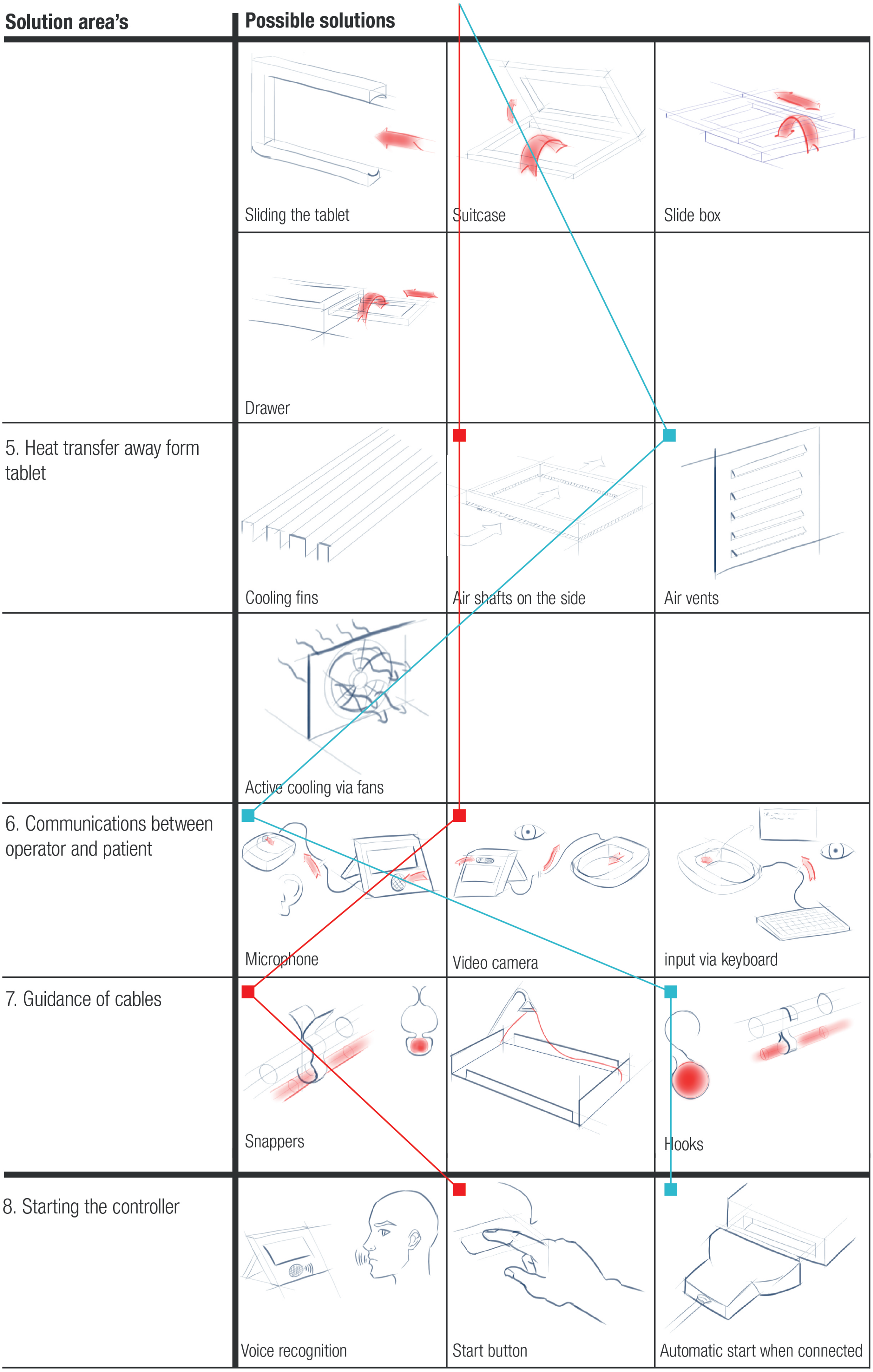

Figure 4.1b | Morphological scheme for generating concepts 1 and 2

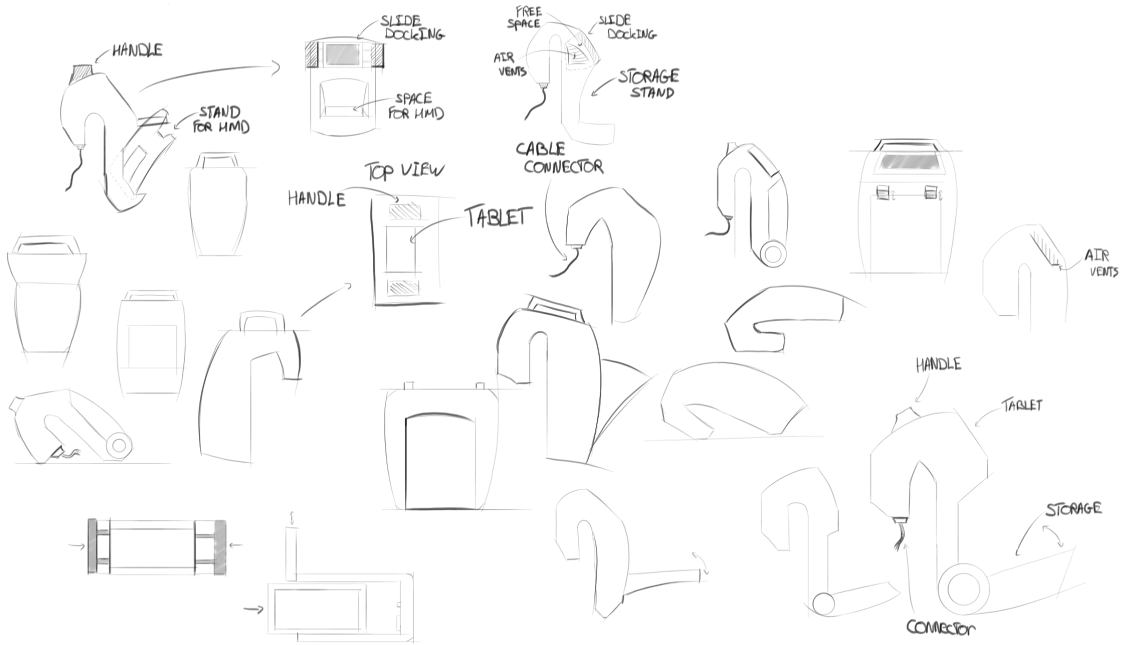

Figure 4.2| Casing ideas that emerged from the red line of the morpholocial analysis

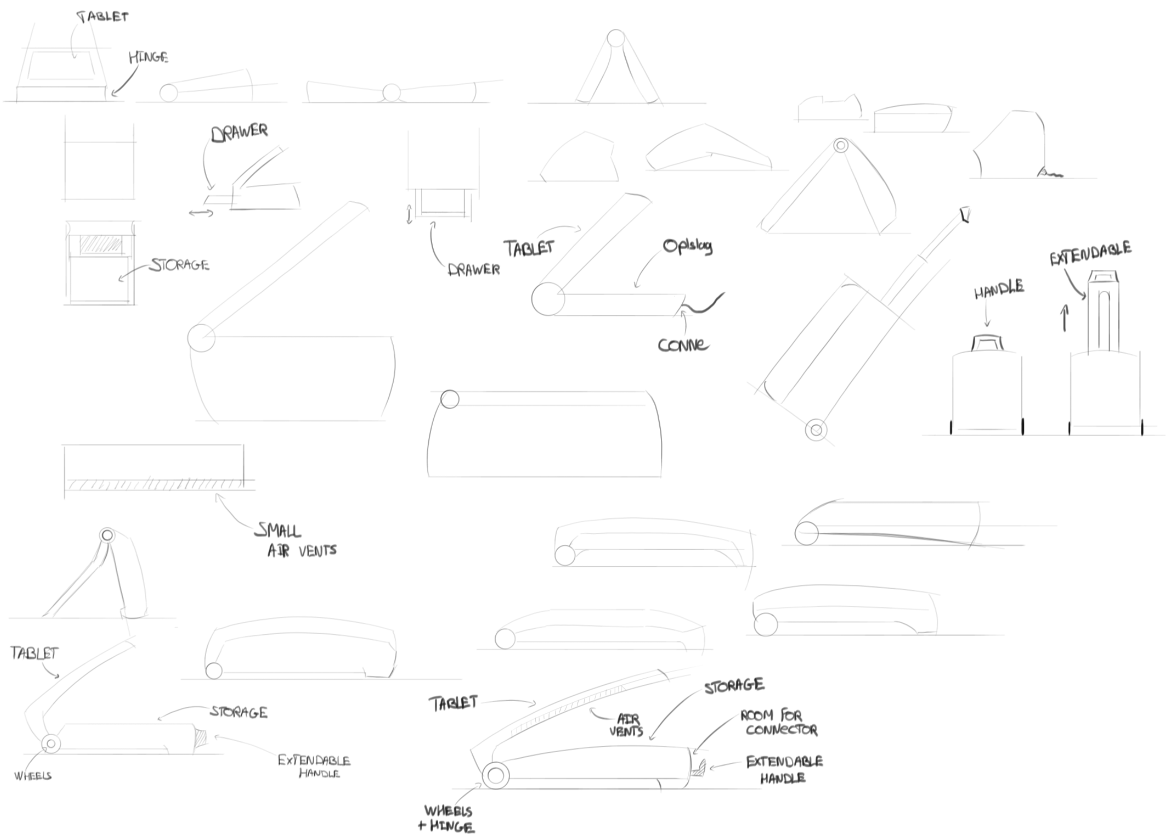

Figure 4.3| Casing ideas that emerged from the blue line of the morpholocial analysis

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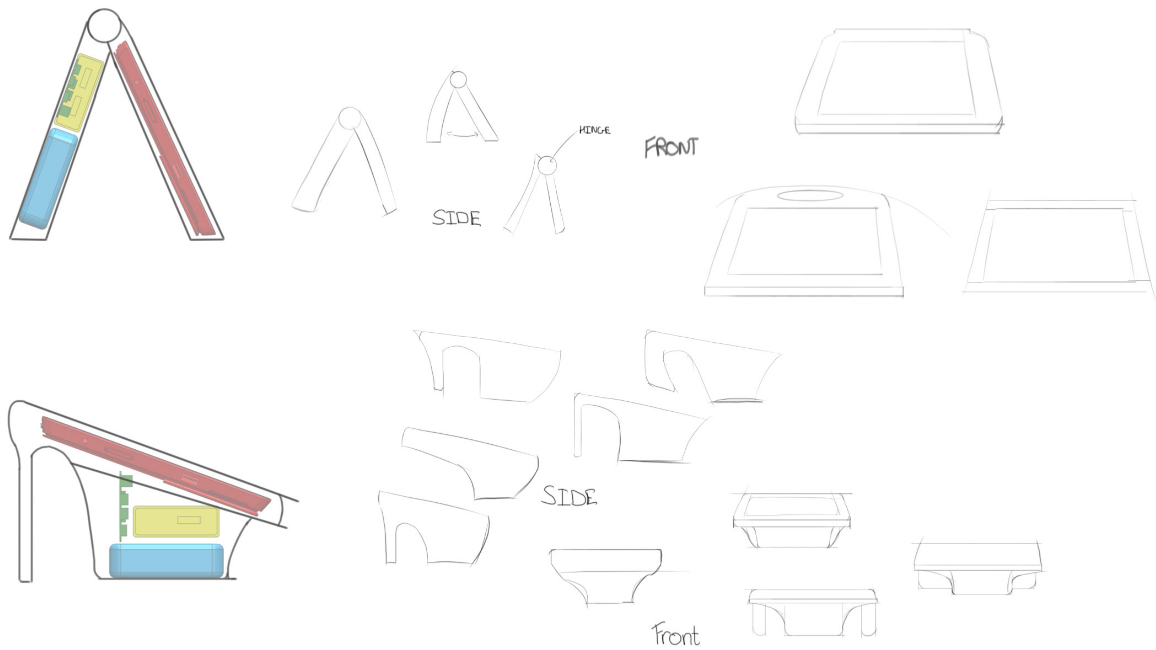

Figure 4.4 | Sketches of embodiment design and ideas that emerged from it

4.2 PRESENTING THE CONCEPTS

In this paragraph the concepts will be presented and detailed information about the sub parts and solutions of the concepts will be given. Concept 1 and 2 arose based on the morphological analysis while concept 3 and 4 originated from the placement of the hardware parts in Solidworks. The description of the concepts is based on the solution areas from *paragraph 3.1*. Not all solution areas are described for each concept because they are not implemented or do not play a big role in the particular concept.

4.2.1 CONCEPT 1

Placement

This concept is placed over de bedrail of the bed that stands in the treatment room. Both of the concepts assume that the most ideal place for the operator of the controller is near the end of the bed. The operator cannot interfere with the other two practitioners standing in this place.

When hanging the controller over de bedrail no extra table is needed. Other than hanging on the edge of the bed the controller can, if needed, also be placed on a flat surface. In the case that the controller cannot be hanged anywhere near the bed, a flat surface is sufficient to make use of the system. The controller has two flattened surfaces (see *figure 4.5*). When the controller lays down on his back the tablet is still visible. The tablet supports rotation of the display. Therefore the operator can access the tablet in both ways.

When the VR system is not used it will be stored in a different room. Here the controller can also be laid down on his back, still allowing the controller to be connected to the power grid to charge the tablet and battery.

Transport
The controller contains an handle that allows the controller to be carried from the storage room to the treatment room. The total weight of the VR system in estimated around three kilograms and is light enough to be carried by one person.

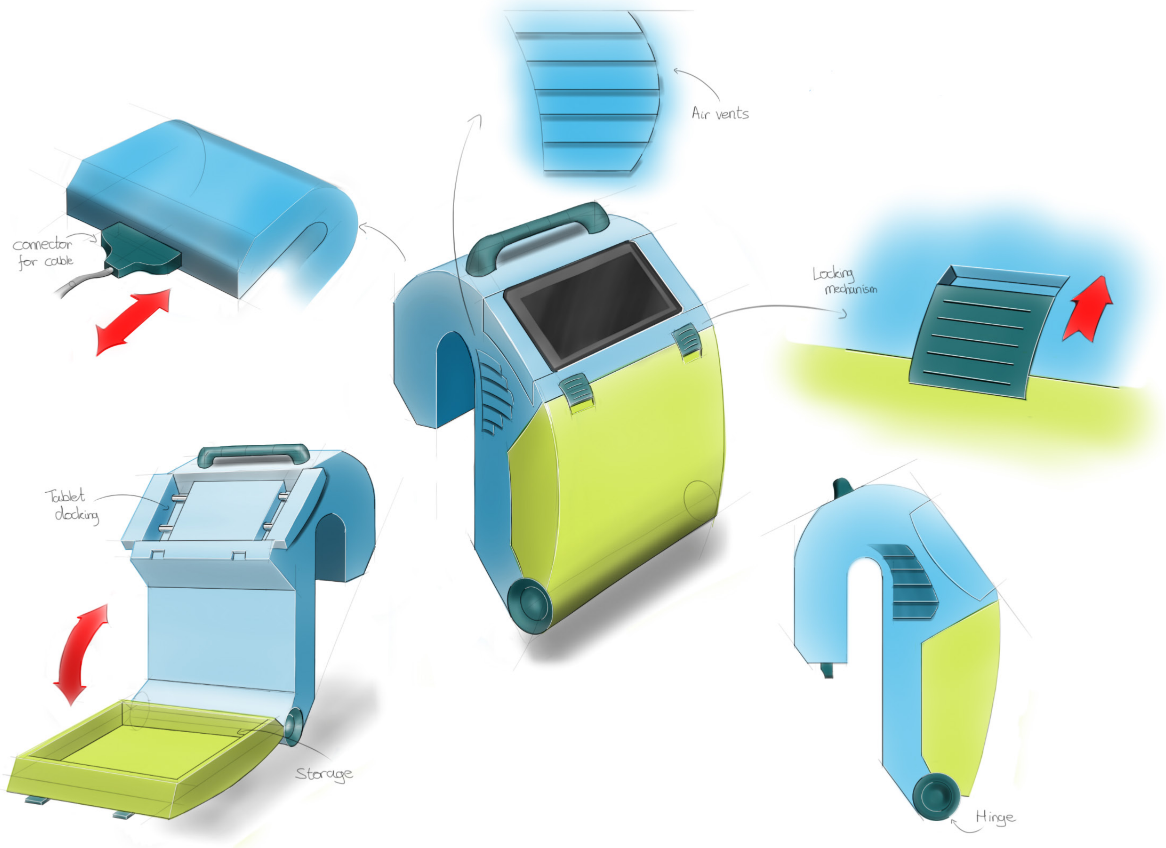

Figure 4.5 | Overview of concept 1

Storage
The front of the controller is reserved for the storage of the HMD and the cable that connects the HMD and the controller. The exact dimensions of the HMD and cable where not known when this concept was made. So no precise solution was made for the specific HMD that would be stored into this controller. However, the HMD and cable need to be protected from shocks and bumps when transported. Therefore a foam inlay is placed inside the storage drawer. This foam inlay fits exactly around the HMD and makes sure it doesn't move around.

The drawer is opened at the top side. There are two lips that can slide up and down and have the function of a lock preventing the drawer from opening. When the two lips are moved up the drawer can be opened and rotates around a hinge on the bottom of the controller. This hinge is a friction hinge which allows the drawer to open up and stand still in every position between 0 degrees and 90 degrees. In this way there is no possibility of the drawer falling open unwanted.

Tablet docking
The tablet can be docked and undocked into the controller. The left and right side that enclose the tablet can be slide to the respectively the left and right. By doing so the tablet is disconnected from the controller and can be moved out of the controller. The sides of the docking station slide over two metal bars that guide the sides to the correct positions.

Cooling
To make sure the active cooling of the tablet can work properly, two air inlets/outlets are placed on each side of the controller. Here cool air can flow into the controller and warm air can leave the controller.

Connecting
The connector for the cable that connects the controller and the HMD is placed at the underside of the controller. This connector point towards the bed mattress and therefore it is easy to guide the cable alongside the bed to the HMD which is mounted on the head of the patient. The connector consists of three inputs (two times a displayport for both the images of the HMD and one USB for the information of the tracker) plus a connector for the accu. The connector for the battery is only used when the controller is placed in the storage room and needs to recharge.

Turning on the tablet
The idea is that the tablet automatically starts when the two display cables are connected. In this way it isn't necessary to pres any buttons or turn on any switches. Another advantage is that the tablet only is turned on when necessary.

4.2.2 CONCEPT 2

Placing
This concept is designed to be placed upon a flat surface. In the treatment room a number of preparation tables are present. The tables usually function as storage space for the head of the nursing staff and the nurse. They store medical equipment on these tables, but these mobile tables can also be used as an side table for the controller. The prep table will be placed at the end of the bed, the ideal location for the VR system.

The top of the product acts as the docking station for the tablet. This lid can be opened by the opened by the operator and can be set in any angle desirable between zero degrees and 90 degrees.

Transport
The controller contains two small wheels on each side. In combination with the handle the controller can be transformed into a trolley. The handle can be put in two different positions. One position where the handle is completely slid into the controller, the other position where the handle is completely out of the controller. The last position of the handle allows the operator to easily transport the VR system throughout the hospital.

When the operator arrives at the treatment room the handle can be retracted into the controller and the controller can be placed upon the prep table.

Storage
Under the lid of the controller a large area can be arranged as storage area for the HMD and the corresponding cables. Inside the storage space there will be a special foam inlay to make sure the components will not shuffle inside the storage space. An exact cut out will be made of the components so the fit precisely into the foam and they will be protected against all kinds of bumps and shocks. The precise lay-out of the foam and the exact space that is needed to store all the components is not yet known because the design of the HMD is not finished.

Tablet docking
The tablet will be docked in the lid of the controller. The tablet can be placed or removed from the controller by accessing the back of the lid. Here two sliders can be slid away from the docking station and thus making room for the tablet to be placed. The connectors need to

be connected before the tablet is placed into the docking area. When the tablet is placed the sliders can be slid back into their original place and in this way keep the tablet from falling out of the docking area.

Cooling
The docking area of the tablet is quite open. There is enough room for air to pass along the tablet. Therefore it will not be needed to take measurements for additional cooling systems. If the air vents of the tablet are accessible to the outer air the tablet will get enough cooling.

Turning on the tablet
The tablet can be turned on by pressing the start button which is located just above the tablet. This has two advantages: a mechanical one and an advantage in usability. The button is now closer to the actual stand by button of the tablet. There is no need to design a complicated mechanical transmission throughout the whole product. On the user side it is the best option to put the start button near the tablet as close as possible. The tablet is the only object that starts up in the experience of the user and therefore it is important to keep the button close to the tablet.

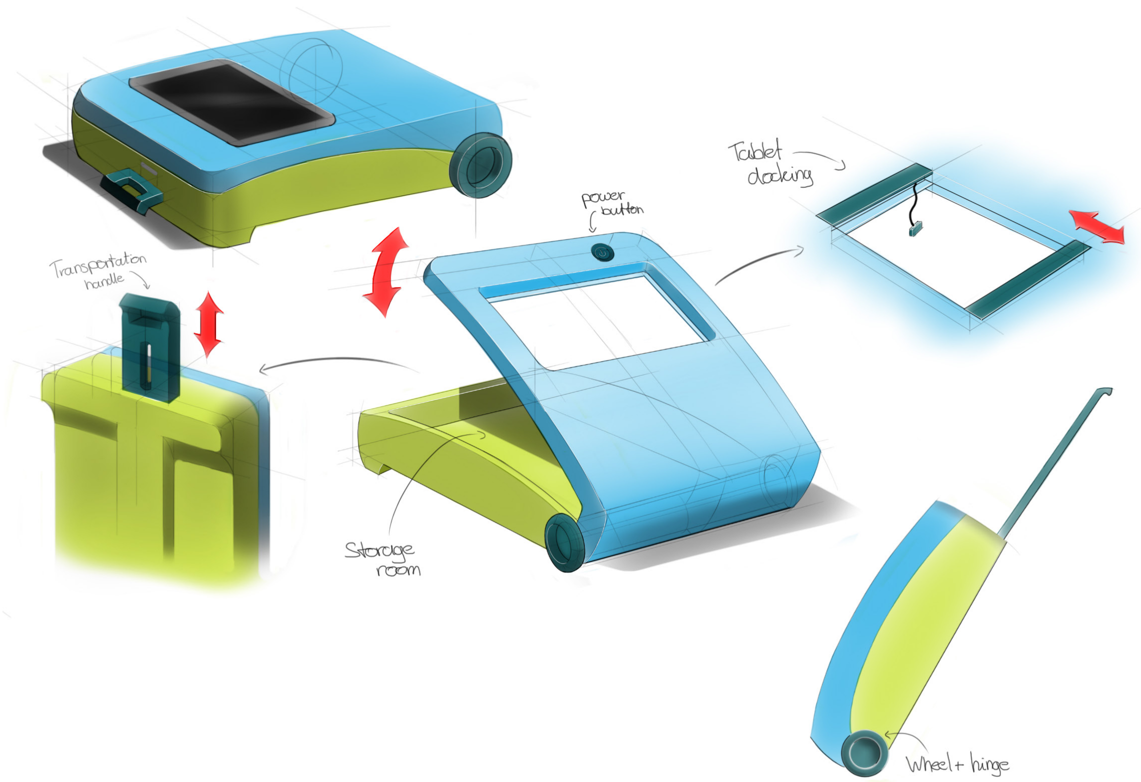

Figure 4.6 | Overview of concept 2

4.2.3 CONCEPT 3

Placement
This concept can hang on the bedrail of the hospital bed. Because this concept does not have any storage space for the HMD and controller the design has become a lot more compact. Because the casing know needs less space it can be hanged on more different places on the hospital bed. The casing can also be placed on a flat surface.

Transport
This concept will be very light and can be carried easily by hand. A handle is placed on the top side of the casing so it can be carried by one hand. On both side of the screen the casing

thickens to enable grasping of the casing when hanging it on the bedrail. The two green pads can be made out of a rougher material what makes it easier the grasp

Storage
In this concept there is no room for storing the HMD or the cable. This ensures that the casing is more compact and easier to transport. Because it is smaller it can also be hung on more places along the bed.

Tablet docking
The tablet can be docked in and out of the casing. There are two sliders on each side of the tablet which are in directly connected to the connectors that need to be inserted in the tablet. By moving the sliders outward the tablet is disconnected and can be lifted out of the casing. When placing the tablet back into the casing the sliders can be moved inwards en the tablet is connected again to all the hardware in the casing.

Turning on the tablet
The tablet can be turned on by pressing the button that is on top of the casing. The button is sunk into the casing so it can't be accidentally touched during a treatment or during transport. The button is in direct contact with the standby switch of the tablet.

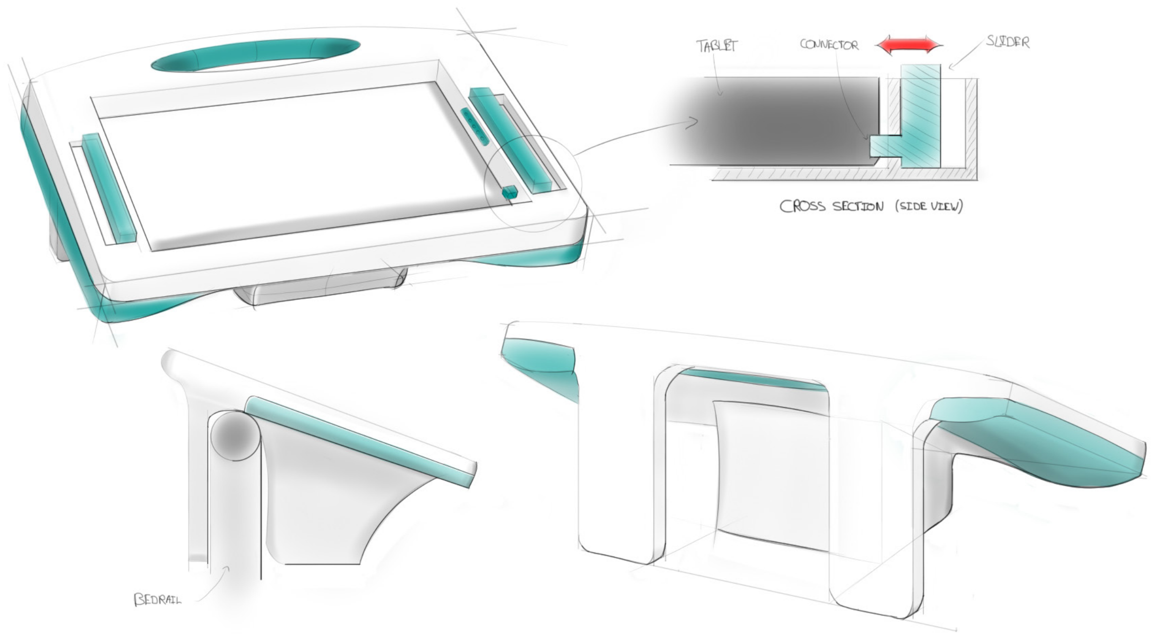

Figure 4.7| Overview of concept 3

4.2.4 CONCEPT 4

Placement
The casing can either be hung on the bedrail of the hospital bed or can stand on a surface. The stand on the back ensures that the product will stand safely on a surface. By placing the casing over a rail the product will hang onto it. By dividing the weight of the components evenly (the tablet in front and the battery in the back) the product will be in balance when hanging. Extra weight can be added in the design to ensure this balance. The hinge that allows the casing to be folded can be used by pressing the button on the side of the hinge. Pressing the buttons unlocks the hinge and the hinge can know pivot between 0 and 45 degrees. Upon releasing the button the hinge will lock again to guarantee that the casing will not slip of the bedrail.

Transport
The HMD and cable are not transported in the casing (similar to concept 3). Therefore the product is much lighter and easily transported by hand. The casing can be folded so the two sides are parallel to each other. It makes the casing very compact and easy to grasp.

Storage
This concept does not store the de HMD and cable of the VR system. The same consideration as for concept 3 is made here.

Tablet docking
Tablet docking is similar to the one in concept 1. There are two sliders on each side of the tablet which can be slit inwards and outwards. In order to unlock the tablet and remove it from de casing the slides need to be moved outward to release the tablet. For docking the exact opposite applies.

Turning on the tablet
The button on the other side of the hinge functions as power button for the tablet. Important is to make a real difference between these two buttons. It has to be clear to the user that one button unlocks the hinges while the other turns on the tablet.

4

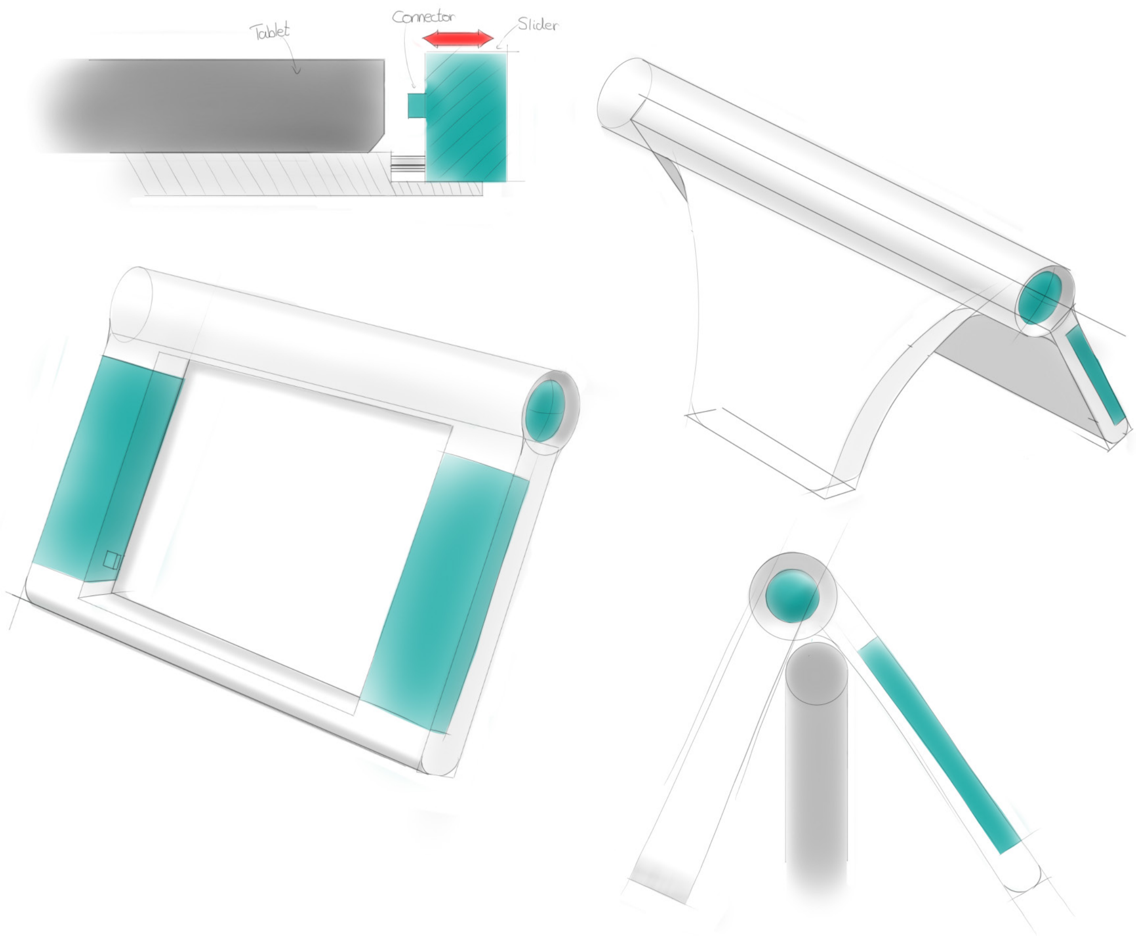

Figure 4.8 | Overview of concept 4

4.3 CONCEPT EVALUATION AND OVERVIEW OF FUTHER DETAILING

All the concepts are compared to each other in order to chose a concept for further development. Two methods are used to make this decision. The concepts are reviewed together with the company and lists of pros and cons are made for each concept to underline the strong and weak point of each concept. Secondly the list of requirements was used to assign a score to each concept based on how well each requirement was met. Multiplying the score with the importance rate of the requirement makes sure that the more important requirements count heavier in the total score.

4.3.1 PROS AND CONS OF EACH CONCEPT

Each concept is evaluated with a group of employees of Cybermind. The findings of this evaluation are categorized into pros (advantages) and cons (disadvantages).

Concept 1
Pros:

- The casing can store every part of hardware required for running the VR system.
- The casing can be placed in two ways. It can hang from a rail or it can stand on a flat surface.

Cons:

- The casing is very large en thereby quite uncouth.
- The storage tray can be problematic. It can be a challenge to fit all components in and there is a high chance that the components can easily fall out of the tray.
- The colour scheme is too playful for medical use and does not fit a medical surrounding

Concept 2
Pros:

- This concept will be very easy to transport around the hospital.
- HMD and cable are well protected during transport and storage.

Cons:

- The wheels of the casing can collect dirt during transport. When the casing is placed on top a table or other surface near the hospital bed dirt could get in contact with the skin of the patient.
- The casing is very large en thereby quite uncouth.
- The casing can only be placed on a flat surface and therefore a table has to be placed in the treatment room which takes up extra space in the room. This can minimize the mobility of the practitioner that is treating the wounds.
- The colour scheme is too playful for medical use and does not fit a medical surrounding

Concept 3
Pros:

- The casing is very small and compact, thereby it is easy to transport, carry and place near the hospital bed.
- The design looks nice and intuitive and feels friendly. Due to its size it doesn’t look to

uncouth or big

- The casing can be placed in two ways. It can hang from a rail or it can stand on a flat surface.
- The styling of the casing connects with medical surroundings it going to be placed in. The colour scheme and shape of the casing match that of other medical equipment.

Cons:

- The casing cannot store the HMD and cable and therefore have to be transported separately.
- The sliders that are used for docking can collect dirt and shove it inside the casing of the product where it is very hard to clean.
- Cooling of all the hardware components can be an issue because all the electronic components are packed close together.

Concept 4
Pros:

- The casing is very small and compact, thereby it is easy to transport, carry and place near the hospital bed.
- The casing can be folded so it can be even smaller and more easy to store and transport
- The casing can be placed in two ways. It can hang from a rail or it can stand on a flat surface.
- The styling of the casing connects with medical surroundings it going to be placed in. The color scheme and shape of the casing match that of other medical equipment.

Cons:

- The balance when hanging the casing onto a bedrail can be an issue. If the hardware components are not placed in balance the casing could easily fall of the rail. There is a risk the hanging mechanism does not work.
- If the cable connecting the HMD and casing is pulled by accident the casing might easily slip of the bedrail.
- Cooling of all the hardware components can be an issue because all the electronic components are packed close together.

4.3.2 GENERAL IMPROVEMENTS FOR DETAILING PHASE

Besides the specific pros and cons for each concept a few global problems that accounted all concepts were found. Also, in consultation with Cinoptics, a couple of topics that needed detailing were determined. This resulted in a list of general improvements that is described below.

Detailing tablet docking mechanism - The operation of the mechanism that enables the docking of the tablet needs more elaboration. Now it is unclear which components are needed and how the different mechanism work.

Use of material – It is important to find a material that meets the hygiene requirements and also suits the production method that is going to be used.

Mechanism for starting tablet – Starting the VR system is done by starting up de tablet. Since the tablet is docked the start button is not reachable anymore. A mechanism for starting the tablet via the outside of the casing needs to be made.

Connectors for cable to HMD – It is not stated where the connector for the HMD and connector for the power supply is attached to the casing.

Cooling of the electronic components - There is a chance that the electronic components in the casing, especially the battery and tablet, could overheat if there is no possibility of cold air running along these components. The cooling in de concepts was not very detailed so a more elaborated plan for the cooling of the cooling of the electrical components has to be made in the final concept.

4.3.3 COMPARISON WITH LIST OF REQUIREMENTS

The concepts are also compared to each other using the list of requirements. For each requirement a concept can score a maximum of 5 points and a minimum of 1 point. Score is multiplied by the importance rate of the requirement. Adding up the scores for each requirement gives each concept a total score. The requirements who cannot be evaluated yet and requirements that concern exact values are left out of the equation.

The results are shown in *table 4.1* and from this point of view a clear distinction can be made between the concepts 1 and 2 and concept 3 and 4 where concept 3 and 4 score slightly better.

4.4 CONCEPT CHOICE AND FURTHER DEVELOPMENT

Based upon the evaluations a choice has been made between the four concepts. Concept 3 has been chosen as basis for the further development of the casing. The concept did not only scored the most points in comparison with the list of requirements but was also the best choice regarding the product description from *paragraph 2.4.2*. The tablet docking system of concept 1 and 4 will be combined with concept 3 because this was evaluated as the most feasible docking method.

It is not certain whether the HMD that is developed alongside this project is to be produced. Because the concept that is chosen does not have a possibility to store a HMD or a cable his concept offers versatility in combining it with other types of HMDs. This is something the company has profit from and gives them the possibility to combine the controller with other HMDs.

All the general improvements from *paragraph 4.3.2* will be taken into account when further developing this product. Together with detailing some other aspects of the casing for the controller de following steps will be made during the elaboration of the final concept:

- Detailing the mechanism for docking the tablet
- Describing which materials and production methods can be used
- Detailing the mechanism for starting tablet
- Describing the lay-out of the hardware components and designing a way to cool the electrical components
- Designing the location for the connectors for the cable that leads to HMD
- Creating a 3D model of the casing for the controller to better understand the architecture of the product and get an idea of the looks of the product.

It is also uncertain whether the casing of the controller will be produced in the near future. It is also unknown how many hospitals will exactly be interested in this product. A brochure will be made of the new VR system (HMD and casing), this can be shown to hospitals in order to inform them about the new product and help them see the possibilities this VR system can offer.

Table 4.1 | Overview of requirements with importance ranking

REQUIREMENTS	IMPORTANCE	Concept 1	Concept 2	Concept 3	Concept 4
Aesthetics					
The controller must connect with the corporate identity of Cinoptics	4	2	2	5	5
The controller contains a simplistic design with minimal distracting features	4	2	3	4	4
The controller must connect with the appearance of modern medical equipment	3	3	3	5	5
The controller must evoke the feeling of a sterile environment to the patient	3	3	2	4	4
Geometry					
The controller may not block the view of the practitioner	5	4	2	4	4
The controller may not block the proceedings of the practitioner	5	4	4	3	3
The controller is suitable for transport by hand by one person	4	4	4	5	5
The controller can be transported through the hospital	5	2	3	5	4
Performance					
The controller can store the HMD and the connector cable	5	5	5	1	1
The controller can dock the tablet that is used to control the game	5	5	5	5	5
The controller can be carried using one hand	2	4	4	5	5
Physical					
The controller does not have small grooves or other small spaces where filth can add up	4	3	2	3	4
The controller can be easily cleaned by medical personnel	4	2	4	4	5
The controller can contain all electronic components and keeps them in place	5	5	5	5	5
The operator can move the tablet towards or away from himself	2	1	4	1	1
The use of the controller doesn't require any changes to the treatment room in UZ Leuven	4	4	2	4	4
Totaal		221	219	292	257

DETAILING

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The starting point in chapter 5 will be the chosen concept from chapter 4. A list of improvements will be elaborated. First a couple of mechanisms will be detailed: the mechanism for the docking of the tablet and the starting button. Also the mounting of the different parts within in the casing is detailed.

Then an overview is given of possible production methods for the production of the final product and for the possible prototypes. Also different materials are analyzed to see which materials are best used for the final product. This will result in a recommendation for the production and material selection.

After this the 3D model that is made in Solidworks is shown. This gives an overview of the final stage of the product for this assignment.

In the last section a small brochure is shown. The aim of this brochure is to inform hospitals or other partners of Cinoptics about the possibilities of the new VR system.

5.1 TECHNICAL COMPONENTS

5.1.1 MECHANISM FOR DOCKING THE TABLET

In chapter 4 the decision is made to incorporate the docking mechanism of concept 1 and 4 which were very similar. This mechanism consists of two sliders on each side of the casing (one slider is shown in top view in *figure 5.1*). Connectors that need to be connected to the tablet (USB, mini-displayport and power connector) are part of the slider.

The slider can slide out the casing for 15 mm. This is enough for all type of connectors to fully disconnect from the tablet so the tablet is free to be removed from the casing. Two metal cylinders will guide the slider and provide the accuracy for the alignment of the connectors from the slider with the connectors from the tablet. In the middle a slot for guidance of the cables is made. A plastic tube will guide the cable from the connector trough the slider, trough the tube into the heart of the casing where all electronics are. The way that the cable runs trought the slider is shown in *figure 5.1*.

The slider will be a separate part in the total assembly of the controller. The casing of the controller will therefore have two open slots where the sliders can be placed.

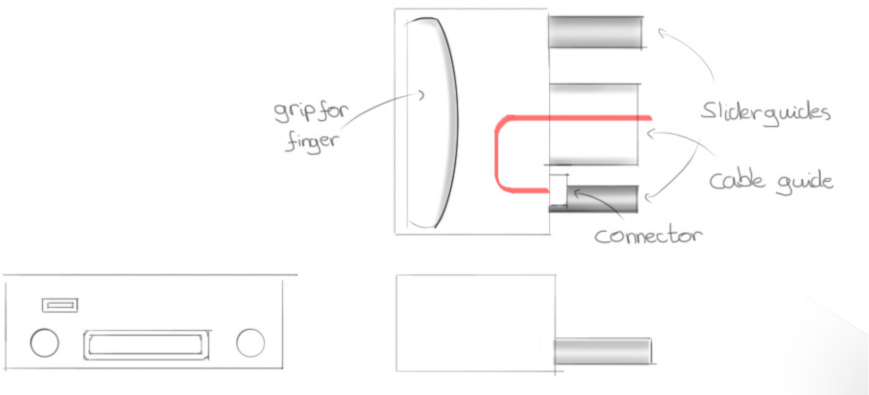

Figure 5.1 | Different views on the slider. The red line is the run path of the cable leading from the connector into the casing.

5.1.2 STARTING BUTTON MECHANISM

In order to start the whole virtual reality system the stand by button of the tablet needs to be pushed. Because there now is a casing surrounding the tablet an extension of this button has to be made so the standby button can be pressed easily.

The solution for this problem has to make sure the button is only pressed short and the mechanism may not get stuck when pressed. When the mechanism keeps pushing the stand by button of the tablet for more than three seconds, the tablet will shut down.

The mechanism that is design consists of a spring button as is shown in *figure 5.2*. During the assembly of the casing the button can be placed into the button hole that is in the casing of the controller. The barbed hooks of the button will make sure the button 'clicks' itself into the casing so it can not fall out of the button hole.

When the button is pressed, the spring will be under pressure. This pressure is released when the user releases the button. In this way the button does not get stuck in the casing. In this way the button will act like an extension of the stand by button of the tablet.

The part of the button that is visible on the outside of the casing is slightly countersunk. This prevents someone of something accidentally pressing the button. An universal standby logo will tell the user the function of the button.

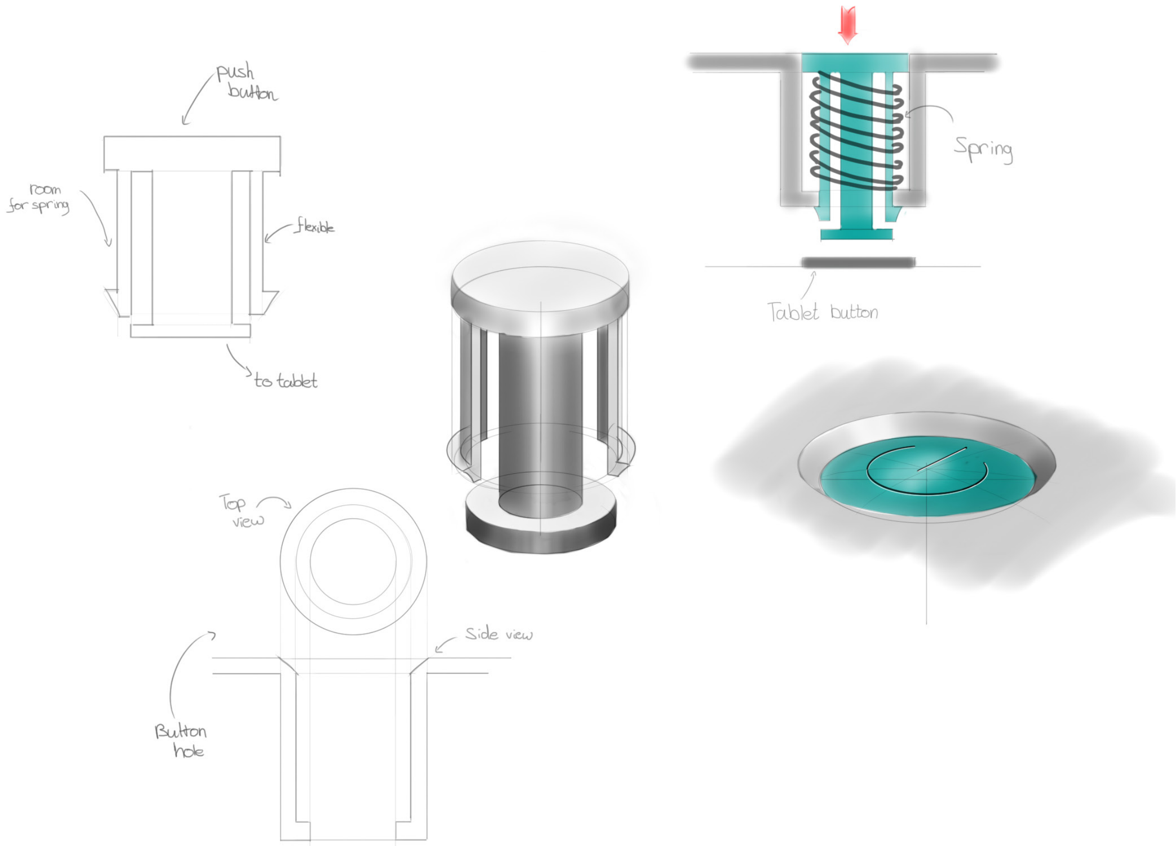

Figure 5.2 | Overview of detailing of the start button.

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5.1.3 LAY-OUT AND MOUNTING OF HARDWARE PARTS

The global lay out of the electronic components in the casing of the controller are determined in *paragraph 4.1.2*. A more detailed view on the lay-out of the hardware parts can be found in *paragraph 5.4*. The next step is to determine how all part will be mounted in the casing. The production method plays an important role in how the hardware parts are mounted in the casing. Details for the production method can be found in *paragraph 5.2*. The results of this paragraph show that for the prototype 3D printing is going to be used and for further production of the final product silicon moulding is going to be used.

The easiest way of mounting the different part is by using screws. With 3D printing it is not possible to print the threads for the screws. The material and production methods are too weak to support the hardware parts. With silicone moulding it is possible to mould the threads directly. Several companies show that is it possible to insert screws into the moulding process. These screw threads can be made even stronger by using metal inserts in the moulding process.

These metal inserts can also be used for the prototype that is 3D printed. The metal inserts will not be embeded in the 3D printing process but have to be added after the casing is 3D printed. The inserts can be glued into predesigned holes of the casing.

Overall it can be said that the most safest and strongest way of mounting the hardware parts is by using metal inserts. These metal inserts can be used in the two different production processes.

Figure 5.3| Example of metal inserts that can be integrated in the mounting of the hardware parts

5.1.4 PREVENT OVERHEATING

As said in *paragraph 4.3.2* the electronical components in the casing will produce heat that in the concept version could not get out of the casing. An air flow has to be created to prevent overheating of the components

The tablet already has an active cooling system with two fans that suck in air on the top side of the tablet and blow hot air out of de other three sides. Of the other electrical components only the battery is expected to produce heat. The cable splitter and cable combiner are not likely to produce any heat. The battery does not have any active cooling and relies on passive cooling.

This means that fresh air must be able to enter the casing somewhere and the most easiest way is by creating a air vent somewhere on the outside of the casing. Preferably the air vent is not directly visible so that it does not affect the look of the casing as a clean and solid design.

The solution was found by placing a vent on the bottom of the product. To let the fresh air enter the inside of the casing the outer rim of the bottom side of the casing is extended (shown in *figure 5.11 and 5.12*). The casing stands on four legs so air can enter trough the vent.

The casing will also need some air vents near the tablet. The air vents of the tablet consist of a small slot that goes around the whole side of the tablet. A similar air vent is made in casing so air can pass through both vents and reaches the inside of the casing. Further detailing on the exact location of all the vents can be found in paragraph 5.4.

5.2 RECOMMENDATIONS FOR PRODUCTION

Before the product has its final shape, evaluations need to be done with a prototype of the casing. It is not expected that after the evaluations a large number of casing is going to be produced. Probably a handful of hospitals will be interested in using this VR system. Maybe that after a longer period more interest is shown by a larger number of hospital, but for now we will look at the near future.

The prototype will be a single product while multiple instances of the final product will be made. The two recommendations for the production method are therefore separated.

5.2.1 PRODUCTION OF FINAL PRODUCT

Limited use of production methods can be used for production of the final product because the product quantity will be low. Rapid prototyping will be the best production method. The cost are relatively low when je produce around 20 or 30 products.

A common used rapid prototyping technique is 3D printing. But the case (rough dimensions: 360 by 240 by 200 mm) can be too voluminous for 3D printing. But when producing 5 or more casings other methods become more interesting when we look at the costs.

Vacuum casting with silicone mould is good alternative. One silicone moulds can produce 10-30 products (the amount varies between different producers and depends on the complexity of the product), and therefore matches the estimated quantity.

Proces of vacuum casting with silicone mold
First a master model of the casing is made using stereo lithography (SLA) or CNC milling. This master model is used to make a silicone mould. This silicone mould is then used via vacuum casting to produce a duplicate of the master model using various polymers. Polyurethane (PU) is a the most common used polymer for this type of casting. Together with the material selection in *paragraph 4.3* a possible manufacturer is chosen.

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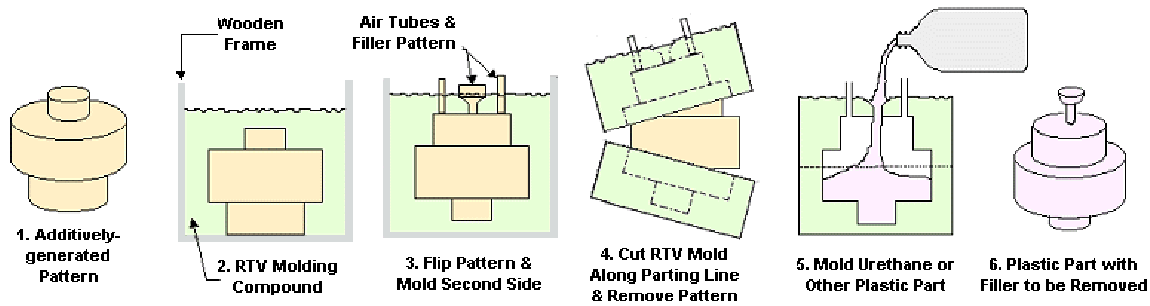

Figure 5.4 | Last steps in the process of vacuum casting with silicone mold

Assembly
The casing will be divided into two large parts (see *paragraph 5.4* for full details). Assembly of the casing, electronic hardware and other parts will take place by hand

The two main parts of the casing need to be combined. Gluing the two casing parts together is best solution when looking to strength, stiffness and toughness. The only downside is that the casing cannot be opened after it is glued together and no maintenance can be performed on the hardware.

5.2.2 PRODUCTION OF PROTOTYPE

Different prototypes shall be made before the final product will be produced. The prototypes will be put to the test to check for flaws in the design . All the prototypes will be single pieces and therefore silicon moulding is not ideal as a production method for the prototypes because silicone moulding becomes cheaper each time the mould is reused.

The production of the prototypes will have different requirements than the final production. For instance the finishing of the prototype is less important because mainly the funcionality is going to be evaluated. A low quality 3D printing method could be a good solution for this type of prototyping. It is cheaper than silicone moulding, the only downside is that durability will be lower, but that in not a problem since the prototype will be used for evaluation and maybe for promotion but not for long term use.

There is a vast variety of 3D printing production methods which all have their advantages and disadvantages. The most common techniques are Fused Deposition Modelling (FDM), Stereo Lithography Apparatus (SLA) and Selective Laser Sintering (SLS). Depending on the use of the prototype a selection between these methods can be made.

SLA
If the prototype is used as model to show the appearance of the product than SLA is a good production method. SLA can produce complex geometries and has the best surface finish compared to the other methods. The cost of this method are relatively low. The downside is that the parts are much weaker and therefore SLA cannot be used for functional evaluation and testing.

FMD
When functional testing is desirable, FDM is a good production method choice. FDM printed parts tend to be much stronger than SLA printed parts. Also production of complex shapes and forms is no problem with FDM printing. The only disadvantage is the poor surface finish, often described as stair-stepping surface or a rippling texture.

SLS
The SLS method stand somewhere between these methods. The accuracy of SLS can be compared to the accuracy of SLA printing. The upside is that SLS is more durable than SLA. The big difference is that SLS has a poor surface finish in comparison to SLA. The surface tends to have a sandy texture. Therefore functional evaluation cannot be done with SLS printed parts.

Together with the material selection in *paragraph 5.3* a possible manufacturer is chosen.

For the prototypes it can be important to check the hardware components that are inside the casing for maintanance purposes. Therefore the two parts of the casing cannot be glued together. The most simple solution is to use screws to fix the two main parts of the casing together so it can be opened at any time. If a prototype is made for appearance purposes only and no hardware parts are present in the casing, the two casing parts can be glued together.

5.2.3. CONCLUSION FOR PRODUCTION

Two different type of product are going to be made: prototypes and final products. These both have different requirements when we look at the production method. The final product will be produced by vacuum casting with a silicone mould. This method suits the amount of products that is desired and also has the best volume/price ratio.

The prototypes will be produced using 3D printing techniques. Looking at the function of the prototype (appearance model or functional model) the exact 3D printing technique can be selected. The most common techniques that should suffice for all the different sorts of prototypes are SLA, FDM and SLS.

The assembly of the two different types of products both can be performed in Leeuwarden where the electronics department of Cinoptics is located.

5.3 RECOMMENDATIONS FOR MATERIAL SELECTION

Often in the medical world material selection is done by looking at previous medical devises, that look the same as the product that you are producing and take over the material selection of that product. Cinoptics uses PP and PET for most of the products. It would be a save choice, but in the section below a small analysis is made with alternative materials as an outcome.

The material of the casing needs to fulfil a certain amount of requirements.

- The casing has to be stiff in order to contain all components
- It needs to be tough so it does not fracture easily
- The material may not react with ethanol (70%) or with chlorine
- The material must be an electric insulator
- The material needs to be able to be vacuum casted using a silicone mould
- The material may not become too hot due to heating of electrical components inside the casing, so it needs to be a good thermal insulator
- In order to minimize the cost the price/kg must be low. Also the casing must not become too heave, so density is also minimized.

These constraints are used as input for CES 2013. CES 2013 is a software program that compares different materials based on a set of restrictions. The restriction for ethanol and chlorine returned only PE as fit material. Different materials who do not react with ethanol and chlorine can be used though, but they have to be coated. Therefore a coating can be applied to prevent corrosion due to these substances .

The restriction that the material needs to be able to be vacuum casted using a silicone mould was difficult to include. CES does not restrict to this specific type of rapid prototyping but does only restrict to rapid prototyping in general. Therefore this restriction was let out of the analysis to allow more materials to find some other interesting materials or conclusions regarding the material selection for the casing.

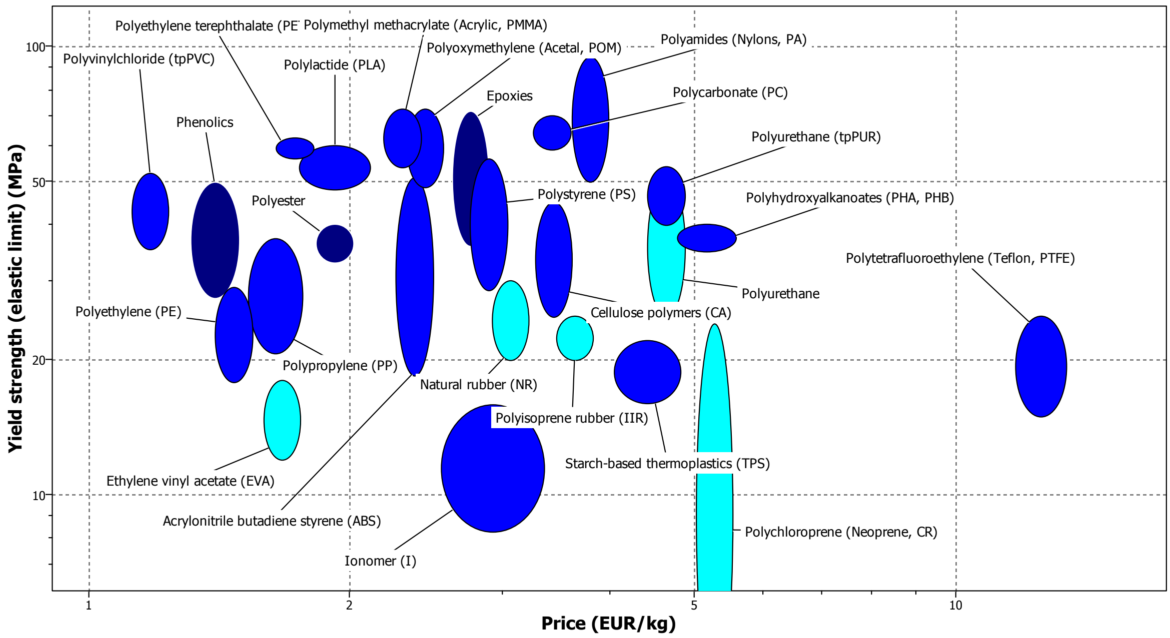

Figure 5.5 | CES analysis; plot of suitable materials for casing (Price ; Yield Strength); dark blue: polymers; light blue: elastomers.

In *figure 5.5* price is compared to yield strength. Yield strength is the stress a material can withstand before the material starts to plastically deform. We are looking for a stiff material that does not easily deform and can easily contain all the components. There is no clear winner after this first analysis, there are a couple of materials in the left corner that can all be a good materials for the casing. These materials are PET, PLA, PVC, PE, PP and ABS. It worth noting that PU is in de middle of the spectrum and is relatively strong, but the price per kg is high.

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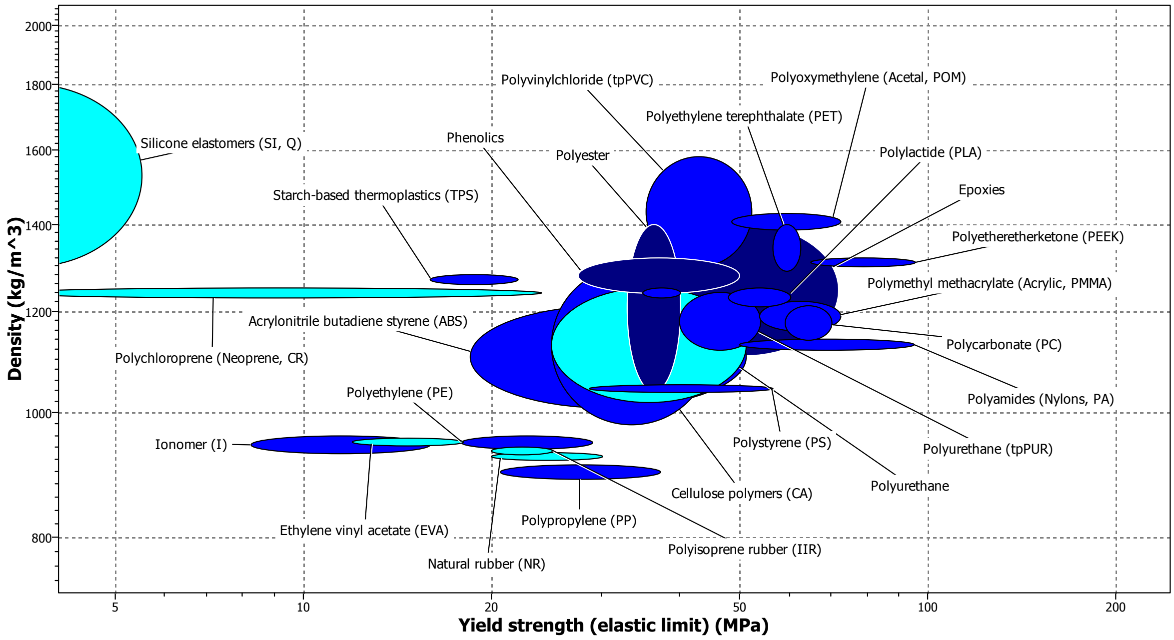

Figure 5.6 | CES analysis; plot of suitable materials for casing (Yield strength ; Density); dark blue: polymers; light blue: elastomers.

In order to try find a better conclusion a second analysis was made. Here the density of the material is taken into account. Lower density means the product will be lighter (in general). Here we see that PVC is a very 'heavy' material, the same goes for PET. The ideal material would be in the lower right corner, where the density is low but the yield strength (e.g. stiffness of the material) is high. Materials that find a good balance between these two variables are PC, PU, PS and PP. An important consideration is to determine that is it more important that the device is stiff enough rather than the density is as low as possible.

The production method that is going to be used for the final production of the casing will be vacuum casting with silicone moulding. It appears that all companies use polyurethane as a basis for the vacuum casting. Different types of PU can be used to approach the properties of other polymers such as PE, ABS and PP.

The use of PU in medical appliances is increasing over the last decade. PU is a very versatile material and due to its toughness, biocompatibility and hemocompatibility it has found its way into many medical devices. With additives it can be formed into a strong elastomer or, in the case of this project, a rigid plastic. The handle of the product could be moulded in a different kind of PU. To provide extra grip on the handle a more rubberlike PU can be used.

In the ideal situation the producer of the casing can produce the prototypes as well as final product. It would also be an advantage if the production facility is located near one of the company locations of Cinoptics. The company RapidPrototyping.NL is a production facility that meets all the requirements for the final production of the casing using vacuum casting. They also offer a wide range of 3D printing techniques for making a prototypes of the casing. Their production facility is located in Overijssel near the University of Twente. Is this way a short lead time is realized between the development of the casing at the university and the production facility.

Selecting the material can be done in consultation with the company and their experts should have knowledge about the best material and the necessity for a coating. They state they have coating to ensure that parts can be cleaned with alcohol and they also state that they have produced product for medical industries.

5.3.1 CONCLUSION FOR MATERIAL SELECTION

PU seems to be the best material for the final product. The main reason for this choice is the excellent fit with the production method of vacuum casting with a silicone mould. Furthermore it also fits the material requirements that were set at the beginning of *paragraph 5.3* and the material offers a great selection of varieties that enables many different material looks and feel.

RapidPrototyping.NL offers all the production methods needed for the final product but also for making a prototype and produces with the materials that are going to be used. In consultation with the production facility a rigid type of PU needs to be selected as well as the coating needs to be selected.

5.4 SOLIDWORKS MODEL

A model of the casing for the controller is made in the 3D environment of Solidworks. The main idea here is to show what the product is going to look like if it were to be produced. In the second place this model can be a starting point for the real production of a prototype of the casing. In the next sections all the parts of the casing are shown and explained together with some explanation of some mechanisms.

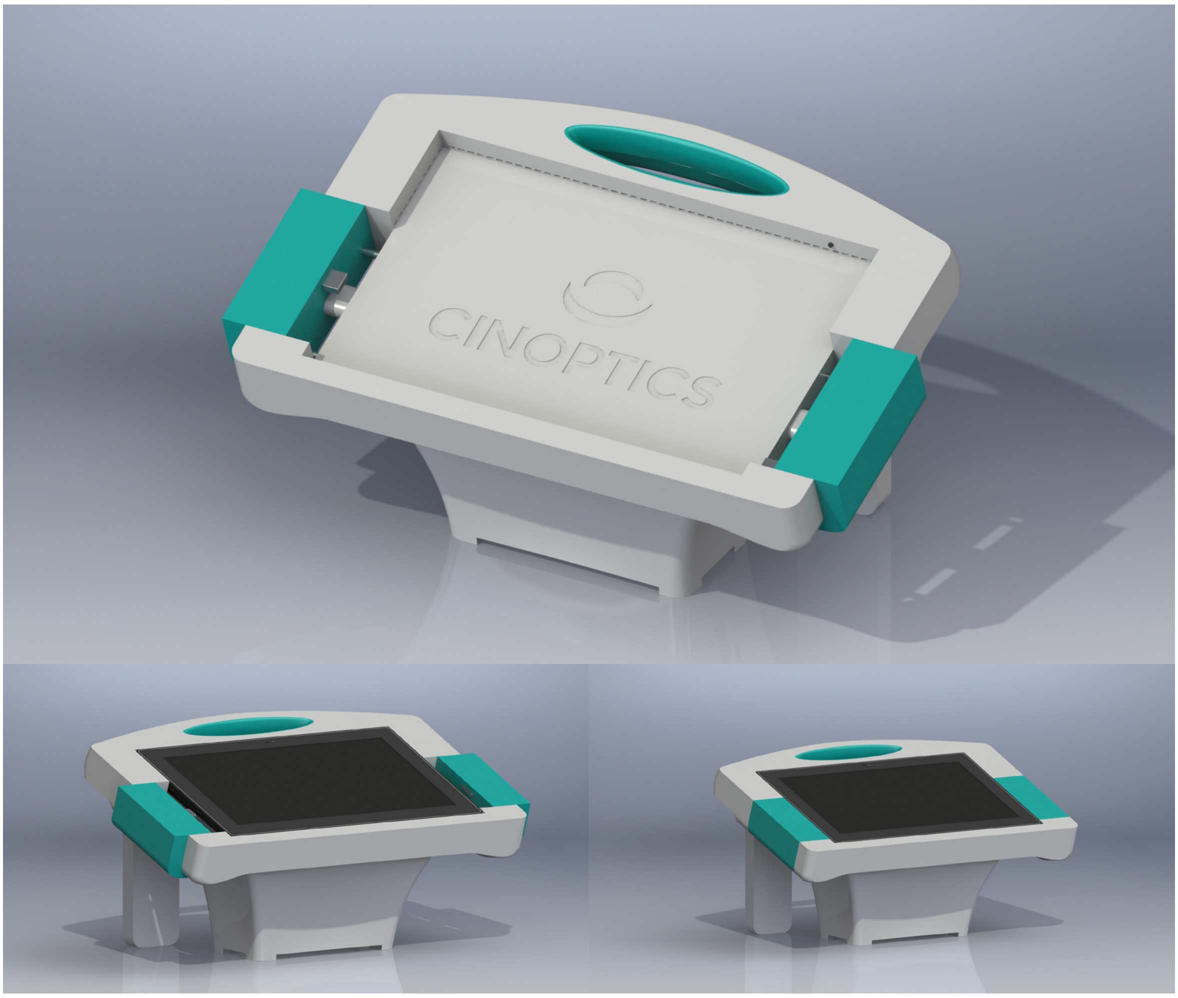

Figure 5.7 | 3D renders of the model made in Solidworks

5.4.1 PARTS OF THE CASING

Bottom casing
The bottom casing forms the basis of the product. This part is the core of the controller were al the electronic hardware is placed. In the middle a partition is placed where all electronics can be mounted onto. The exact dimensions of the electronics are not known, therefore is was impossible to model the exact mounting mechanism. The global dimensions of the hardware components are known and therefore the location of the components are indicated (see *figure 5.8)*.

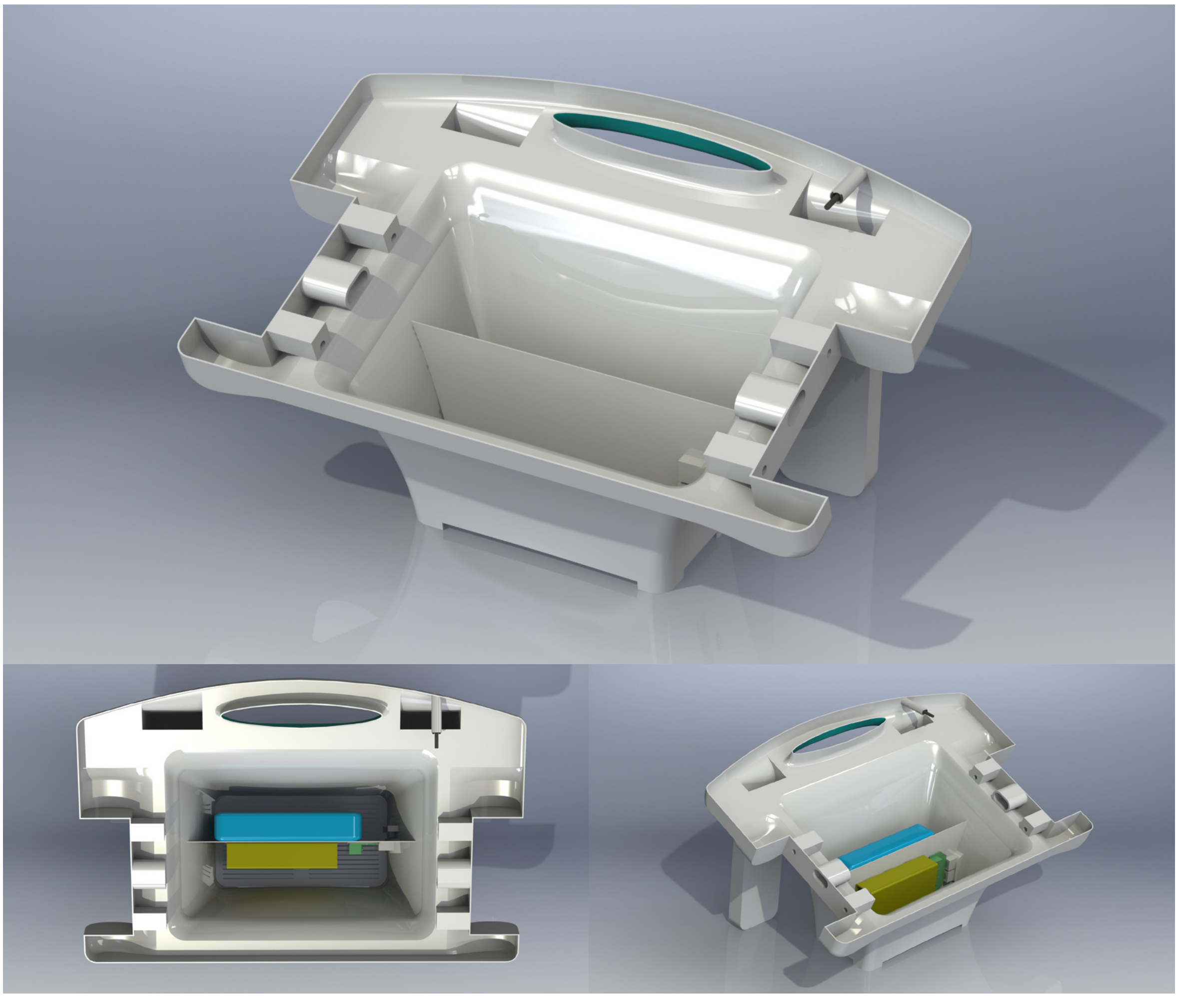

Figure 5.8 | Bottom part of the casing and lay-out of electronic hardware parts. The colours correspond with the color used ealier in this report. Bleu: battery pack, yellow: cable splitter, green: cable combiner.

The bottom casing also contains the two bars that fall around the rail of the hospital bed in order to hang the casing on a hospital bed. Together with the back of the core of the controller the casing clamps onto a bed railing. In the side view you can see the gap getting more narrow to the top, this ensure that multiple diameters of bed railing are suited for handing the casing.

On both sides of the bottom casing the connections for the sliders are integrated. Two cylinders that will contain the metal guidance of the slider and one connection tube to run the cables from the tablet to the different hardware parts.

Top casing
The top casing will house the tablet of the VR system. Together with the bottom part the handle of the casing is formed. The handle is made from a more rubberlike material and therefore is a different material than the rest of the casing. The rubber will provide more grip and has another colour to emphasize the user interaction.

The top casing also contains a engraving of the Cinoptics logo, this increases the connection between the corporate identity of Cinoptics with the product. The colours of the materials are also derived from the new corporate identity.

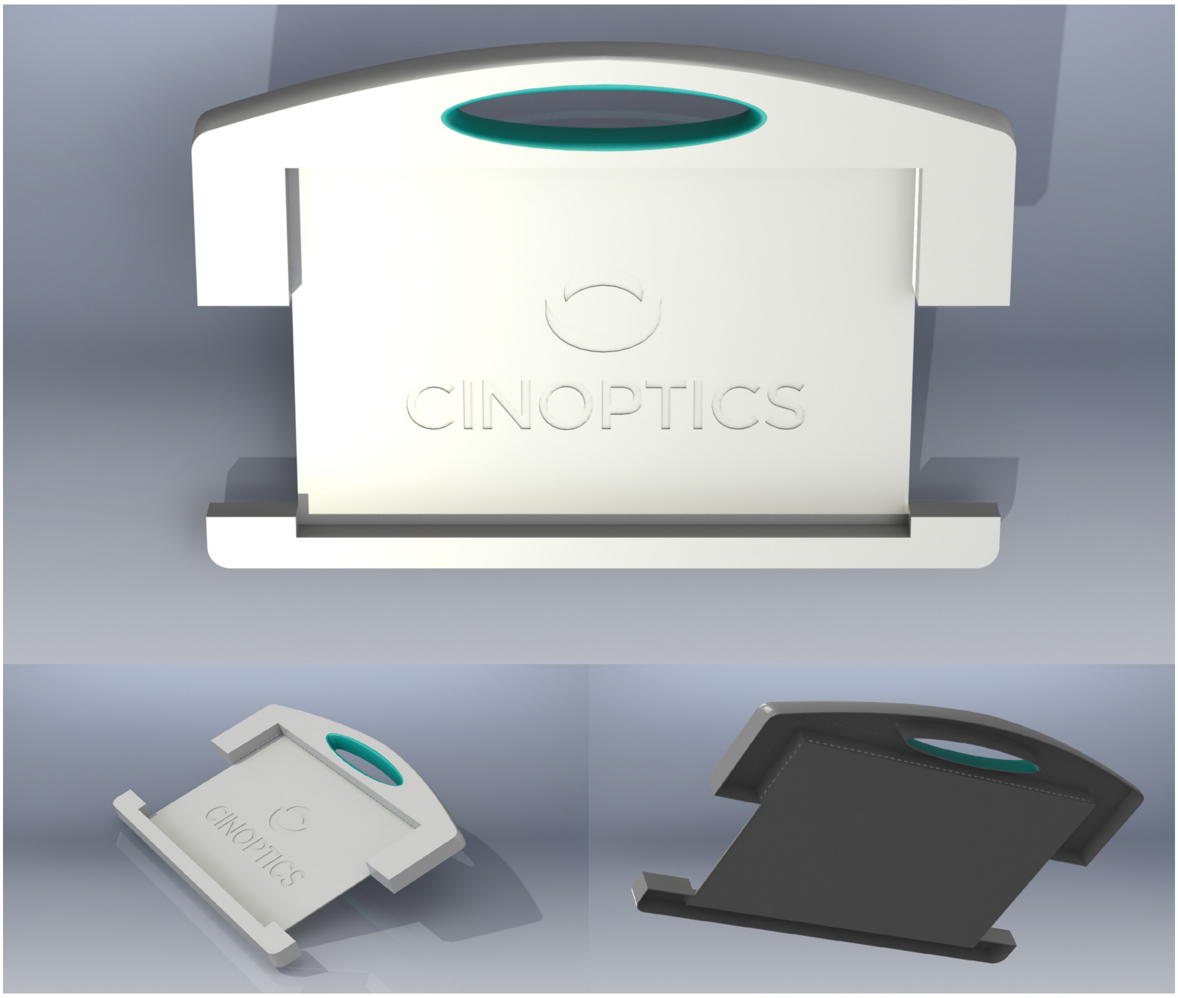

Figure 5.9 | 3D renders of the top casing part

Sliders

There are two sliders on both sides of the casing. The sliders enable the docking of the tablet. By moving hem inward or outward the tablet can be connected or disconnected. The sliders are made of the same material as the handle on top of the casing to provide better grip and ensure unity in the product.

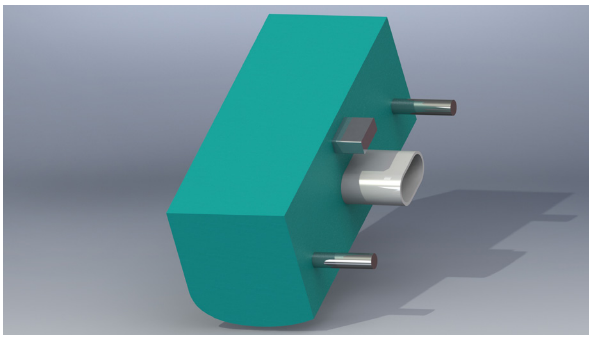

Figure 5.10 | Close-up of the slider

Cooling
To prevent overheating of the electrical components fresh air is needed to cool. By adding different vents in the design fresh air can pass along all components. Air vents along the inside of the top casing enable fresh air to move in and out of the tablet. On the bottom of the casing an grid is placed. This allows air into the core of the casing where all electronic hardware is.

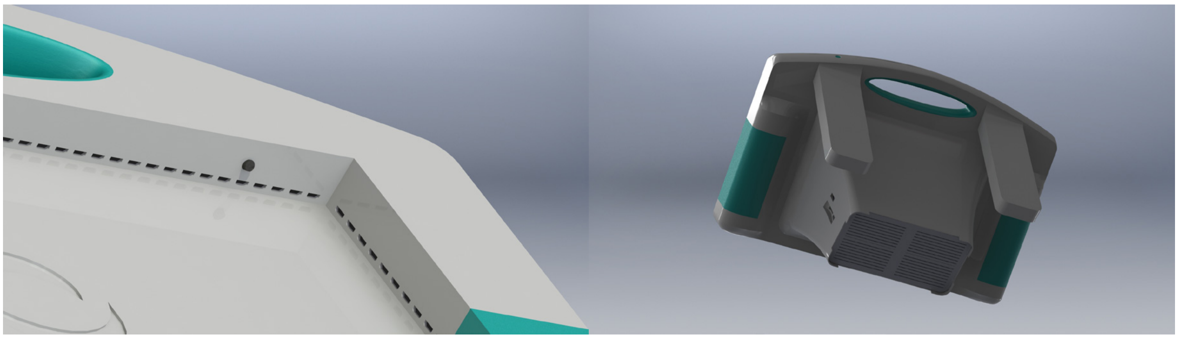

Figure 5.11 | Details of the air vents in the casing. Left the small air vents for the tablet, on the right the bottom of the casing with the ventilation grid

Connecting cables
Three cables need to connected for the VR system to work. When playing the game the controller is connected to the HMD. Two displayport connectors can connect via the right side of the casing. Besides these two connector a power connector is placed. This is connected to the battery pack and with an USB connector the battery pack can be charged when the controller is stored.

Starting
The starting button is on the topside of the casing (see *figure 5.12*). This button is in direct contact with the standby button of the tablet. By pushing the button the tablet can be put into sleep mode. When long pressing the button the tablet will shut down. Also the start button is made of the same material as the handle and sliders.

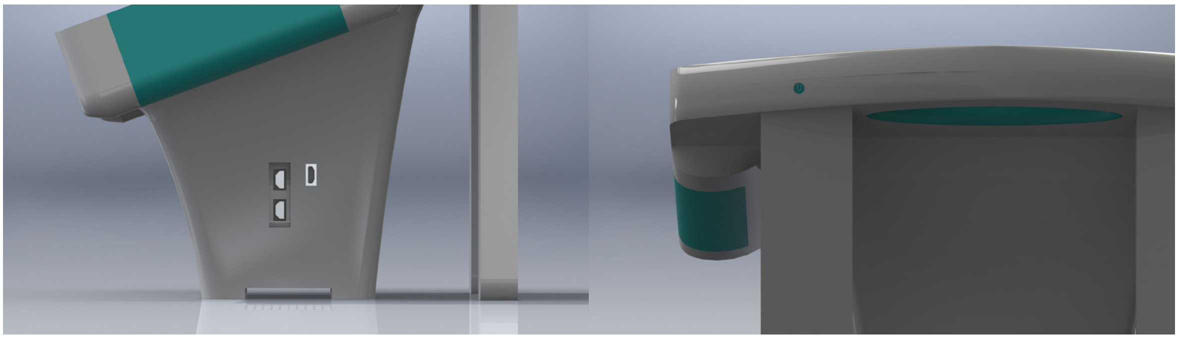

Figure 5.12 | Details of the connectors and start button of the controller

5.5 BROCHURE

The product that is developed in this assignment is a completely new product in the portfolio of Cinoptics. It is important that the hospitals and other contacts of Cinoptics understand the meaning of this product. A brochure is designed to inform them about the product and its possibilities. This brochure can be found in *appendix G*.

CONCLUSION, RECOMMENDATIONS AND EVALUATION

6

In this last chapter we conclude this assignment by describing the results of this design process. Also some recommendations are made for the further development of this product by defining the possible next steps Cinoptics can make in order to realize this product.

Finally we take a look at the whole design process and try to evaluated the steps that are taken.

6.1 CONCLUSION

In this assignment a casing is designed for the controller of a virtual reality system for use in a hospital environment. The controller is a product that contains all electronic hardware that is needed for the VR system to work. In combination with a head mounted device (HMD) the VR system is complete. The assignment can be seen as a redesign of the old controller. However, this old controller was a temporary solution for the problem of transporting a keeping together all electronic hardware parts. The new design is approached as a new product in the portfolio of Cinoptics which has possibilities of using it in multiple settings. In this assignment the hospital setting was the starting point of the design.

The most important piece of hardware in the controller is the tablet from which a game can be played to distract the patient during medical treatment. The tablet can be docked and undocked into the controller. Furthermore the controller consist of a battery pack, which allows the controller to be used wireless, and electronics that take care of the signalling of data from and to the HMD.

The most important problems that needed to be solved in this design were the following:

- The product should be more time efficient. Currently the product takes too long to transport and takes too much time to set up.
- The medical practitioners should be able to view at the screen that shows the images that the patient is seeing at that exact moment. They need to know if the VR system works as desired and if the patient actually experiences immersion.
- The product should be very easy to clean and disinfected if necessary.

The designed controller is an easy to handle product with a minimalistic design. The controller can be hung on the rail of bed or can stand on a flat surface and is easy to set up. This will help the medical practitioners to set up the VR system quicker than before.

Via the tablet the medical practitioner can now see what the patient is seeing trough the HMD. The controller can now be placed on multiple places of the bed railing and therefore the practitioner can always place the controller somewhere near to him.

All the hygienic guidelines are taken into account when selecting the material. Also due the minimalistic design the shape of the controller is made with as little edges and grooves as possible. In this way the controller can easily be cleaned.

A 3D model of the casing was made in Solidworks to communicate the design. This 3D model is a starting point for further production of a prototype. With the renders made from the 3D model a brochure is made to inform hospitals and other possible clients about the controller and its possibilities.

6.2 RECOMMENDATIONS

The delivered 3D model is not yet ready for production of a prototype. Some details about the electronics were unclear at the finish of this assignment. When this details are clarified the model could be adjusted for proper prototyping. Together with the recommendation about the production method a prototype can be made to evaluated different aspects of the casing. Is it strong enough, is the product easy to clean conform the hygiene regulations and how is the user-product interaction with the controller.

These evaluations can lead to improvements of the design of the casing. These adaptations can lead to changes in the final design before it is going to be produced. The hospital of UZ

Leuven has been long involved with this project and could surve as a first real test of the final product. From this point other hospitals can be approached with the result form the UZ Leuven.

An interesting course of events is the introduction of Microsoft's new surface tablet the Surface Pro 3. This renewed version of the tablet that is used in the controller could mean an improvement for the designed product. The main benefit would be that the Surface Pro 3 no longer has connectors on both sides of the tablet. This enables other and easier docking methods which could further simplify the design of the casing

6.3 EVALUATION OF ASSIGNMENT

This assignment proceeded with some up and downs, which are common in design. But it is always good to evaluate these ups and down and reflect possible flaws in the process so this can be prevented in further assignments. In the next few sections a few striking features in the design approach are highlighted.

Analysis
The analysis overall went quite well. All questions that arised about the product, environment and procedures could be answered. The only important issue that was missing, was good contact with the end-user: the medical practitioners. Via devious ways little information about this topic was obtained. Because of this the requirements form the end-user are maybe not mapped as perfect as wanted and further research on this topic could get more insight in making improvements to the design.

Ideation
The ideation phase is not one of my strongest skills in the design process. And in hindsight it maybe was better to approach this phase in a different way. Rather than clinging onto the idea of a controller Cinoptics envisioned, it may have been better to really (re)design the product. Because this type of product did not already existed, completely different ideas could have been made that not continued on the idea of a casing placed somewhere near the hospital bed. In this way a much more innovative product could have been developed.

Concept
When looking at the concepts we can see a difference in the level of detail. This differences can influence the choice between the concepts. In hindsight it would be better to elaborate all the concepts on the same nine solution areas stated in *paragraph 3.1* to enable a equal selection between the concepts.

REFERENCES

"3D Printen, 3D Prototyping, 3D Scannen." RapidPrototyping.nl. N.p., n.d. Web. 15 Sept. 2014. <http://www.rapidprototyping.nl/>.

"Burns: MedlinePlus." U.S. National Library of Medicine, n.d. Web. 15 Sept. 2014. <http://www.nlm.nih.gov/medlineplus/burns.html>.

"Cast Urethane; Design Guidelines." Solid Concepts. Solid Concepts Inc., n.d. Web. 15 Sept. 2014. <http://www.solidconcepts.com/resources/design-guidelines/cast-urethane-design-guidelines/>.

"Cybermind Corporate Information." Cybermind Corporate Information. N.p., n.d. Web. 15 Sept. 2014. <http://www.cybermind.nl/Corporate/corporate.html>.

De Bruyn, A. C.P., B. Van Klingeren, and W. P.J. Severin. Beleid Reiniging Desinfectie En Sterilisatie. Rep. N.p.: Werkgroep Infectiepreventie, n.d. Print.

Faber, Albertus W., David R. Patterson, and Marco Bremer. "Repeated Use of Immersive Virtual Reality Therapy to Control Pain During Wound Dressing Changes in Pediatric and Adult Burn Patients." Journal of Burn Care & Research 34.5 (2013): 563-68. Web.

"Help Brandwonden Kids." Help Brandwonden Kids. N.p., n.d. Web. 15 Sept. 2014. <http://www.helpbrandwondenkids.be/>.

Hoffman, Hunter G., Gloria T. Chambers, Walter J. Meyer, Lisa L. Arceneaux, William J. Russell, Eric J. Seibel, Todd L. Richards, Sam R. Sharar, and David R. Patterson. "Virtual Reality as an Adjunctive Non-pharmacologic Analgesic for Acute Burn Pain During Medical Procedures." Annals of Behavioral Medicine 41.2 (2011): 183-91. Web.

"In De Hel Werken Ook Engelen." Dagblad Van Het Noorden 29 Dec. 2012: 8-11. Print.

Li, Angela, Zorash Montaño, Vincent J. Chen, and Jeffrey I. Gold. "Virtual Reality and Pain Management: Current Trends and Future Directions." Pain Management 1.2 (2011): 147-57. Web.

Mahrer, Nicole E., and Jeffrey I. Gold. "The Use of Virtual Reality for Pain Control: A Review." Current Pain and Headache Reports 13.2 (2009): 100-09. Web.

"Minder Pijn in Virtuele Wereld." Trouw n.d.: n. pag. Print.

Price, D. D. "Psychological and Neural Mechanisms of the Affective Dimension of Pain." Science 288.5472 (2000): 1769-772. Web.

"Prototyping Process." Proto Labs, Inc., 2009. Web. <http%3A%2F%2Fwww.appliancedesign.com%2Fext%2Fresources%2FWhitePapers%2FPPWP-FINAL.pdf%3F1355776273>.

"Rapid Prototyping." Rapid Prototyping. Rapitypes, n.d. Web. 15 Sept. 2014. <http://www.rapitypes.com/activities-rapidprototyping.html>.

"Rapid Tooling and Metal Parts by Additive Fabrication." Castle Island's Worldwide Guide to Rapid Prototyping. Castle Island Co., n.d. Web. 15 Sept. 2014. <http://www.additive3d.com/tl_20.htm>.

"Rapid Tooling and Metal Parts by Additive Fabrication." Castle Island's Worldwide Guide to Rapid Prototyping. Castle Island Co., n.d. Web. 15 Sept. 2014. <http://www.additive3d.com/tl_20.htm>.

Reiniging En Desinfectie Van Ruimten, Meubilair En Voorwerpen. Rep. N.p.: Werkgroep Infectiepreventie, 2009. Print.

Schilders, Hélèlene. "Sneeuwballen Tegen De Pijn." De Volkskrant 05 Apr. 2008: 5-6. Print.

"Silicone Mold Vacuum Casting." Industrial Man. Industrial Man, n.d. Web. 15 Sept. 2014. <http://en.gyrmodel.com/SiliconeMoldVacuumCasting.html>.

Steuer, Jonathan. "Defining Virtual Reality: Dimensions Determining Telepresence." Journal of Communication 42.4 (1992): 73-93. 15 Oct. 1993. Web. <http://ww.cybertherapy.info/pages/telepresence.pdf>.

Strickland, Joanathan. “HowStuffWorks “How Virtual Reality Works”” HowStuffWorks. N.p., n.d. Web. 15 Sept. 2014. <http://electronics.howstuffworks.com/gadgets/other-gadgets/virtual-reality.htm>.

Tweakers. “Microsoft Surface Pro 2 128GB Zwart.” N.p., n.d. Web. 15 Sept. 2014.

“Vacuum Casting: Materials & Datasheets.” Materialise. Materialise, n.d. Web. 15 Sept. 2014. <http://manufacturing.materialise.com/vacuum-casting-materials-datasheets>.

Van Brussel, Michel. “Virtuele Sneeuw Verzacht Pijn Van Brandwondenpatiënten.” KU Leuven. KU Leuven Nieuws, 16 Feb. 2012. Web. 15 Sept. 2014.

Van Wijck, Frank. “Brandwondenpatiënten Virtueel Afgeleid Van Pijnlijke Verbandwissling.” WCS 20.4 (2004): n. pag. Web.

Wright, James I. “Using Polyurethanes in Medical Applications.” MDDI. Medical Plastics, 1 Mar. 2006. Web. 15 Sept. 2014. <http://www.mddionline.com/article/using-polyurethanes-medical-applications>.

DEFINITIONS

Analgesia - “Painlessness”. The absence or reduction of the experience of pain. This can achieved by using painkillers (drugs) or for instance being immersed in a virtual reality.

Cable combiner - Electronic device that combines different input signals (for instance: video, usb data and power) into one output (for instance displayport) therefore allowing all data to be transported over one single cable.

Cable splitter - An electronic device that separates one video input signal into two video output signals. The HMD consist of two video screens: one for the left eye and one for the right eye. Those screens need slightly different images to create the 3D effect in a HMD

Controller - The device that contains all electronic device that are needed in order to successfully run a virtual reality system. Usually it is combined with a head mounted display

Head mounted display (HMD) - Also referred as virtual reality goggles. The headset that the user wears when making use of a virtual reality system. In the HMD visual images create the feeling of a virtual environment.

Virtual reality system (VR system) - Consists of a controller and a head mounted device. Forms all the hardware that is needed to be in a virtual reality.