ULTIMO Patient Monitor

Intensive Care Alarm System

TU Delft / Critical Alarms Lab / Pinch Studio ultimo

ULTIMO Patient Monitor

Final Report

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Group Work

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Erasmus MC
Wytemaweg
(Nacht)ingang

TABLE OF CONTENTS

Contents 5

Abstract 6

Introduction 7
- 1.1 Introduction 8
- 1.2 Context 9
- 1.3 Starting point 10
- 1.4 List of Requirements 11
- 1.5 Challenges 12
- 1.6 Plan 13

The System 15
- 2.1 Hardware 16
- 2.2 Logic 18
- 2.3 Software 22
- 2.4 System usage 24

The Design 25
- 3.1 Iterative design process of the monitor 26
- 3.2 The PC 27
- 3.3 Display 28
- 3.4 Sensor panel 29
- 3.5 Camera 30
- 3.6 Beacons & card 31
- 3.7 Cost 31
- 3.8 Design and research of the screen 33

Prototyping 34

Testing 44
- 5.1 MATLAB Simulation of the system 45
- 5.2 System program Testing 48
- 5.3 Final test 50
- 5.4 Test on Program of Requirements 52

Conclusion 53

Future 56
- 7.1 Software 57
- 7.2 Embodiment design 58
- 7.3 Product experience 60

Reflection 61

Reference 63

Appendix 64
- A. Technical Drawings
- B. Stakeholder Analysis
- C. Concept Ideas
- D. Ergonomics Report Paper
- E. Sustainable impact of Ultimo
- F. Sensor Research
- G. Local server code
- H. Agenda of the Erasmus MC new ICU visit
- I. Questionnaire for professionals - Teus.
- H. End of week briefing

Abstract

As part of the Critical alarms lab’s silent ICU project, Pinch studio developed the UltiMo: A smart ICU monitoring system. The silent ICU aims to reduce stress and anxiety in the intensive care. It aims to create a calm place for patients to recover, allows visitors to feel less anxious about their loved ones and improves clinicians work environment. The UltiMo adjusts the patient monitor inside each patient room based on who is in the room.

Pinch studio developed the system using a camera and Bluetooth beacons. The camera counts the number of people entering and leaving the room. The pc identifies clinicians by the beacons placed on their identity card. This data enables the UltiMo to see when a patient is alone in the room so that the monitor can be set to the silent patient mode. Furthermore, due to the beacons, the system is able to differentiate between visitors and clinicians. The UltiMo introduces a visitor mode, a screen that provides easy to understand information catered to the visitors' knowledge and needs.

Lastly, Pinch studio redesigned the patient monitor so that it represents the UltiMo well. The new design has a clean, friendly and modern look that conveys the intelligence of the system.

INTRODUCTION

This report discusses the process of the development of the UltiMo by Pinch studio. Pinch studio is a multicultural design team from the faculty Industrial Design Engineering of the Delft University of Technology. The UltiMo is an Intensive Care patient monitoring system that changes the monitor behaviour based on who is in the patient room. As of now, the IC is a stressful environment for all parties involved(patients, visitors and clinicians). The Goal of Ultimo is to reduce this stress by adjusting to the users' needs.

1.1 Introduction

For pinch studio the design brief was stated as follows:

This report discusses the process of the development of the UltiMo by Pinch studio. Pinch studio is a multicultural design team from the faculty Industrial Design Engineering of the Delft University of Technology. The UltiMo is an Intensive Care patient monitoring system that changes the monitor behaviour based on who is in the patient room. As of now, the IC is a stressful environment for all parties involved(patients, visitors and clinicians). The Goal of Ultimo is to reduce this stress by adjusting to the users' needs.

During half a year the concept idea of the UltiMo was developed into a working prototype. The UltiMo is part of a bigger project that has been started by the Critical Alarms Lab. Critical alarms lab is working with the various Hospitals, including Erasmus Medical Centre in Rotterdam, where there is a patient room dedicated to new technologies and innovations.

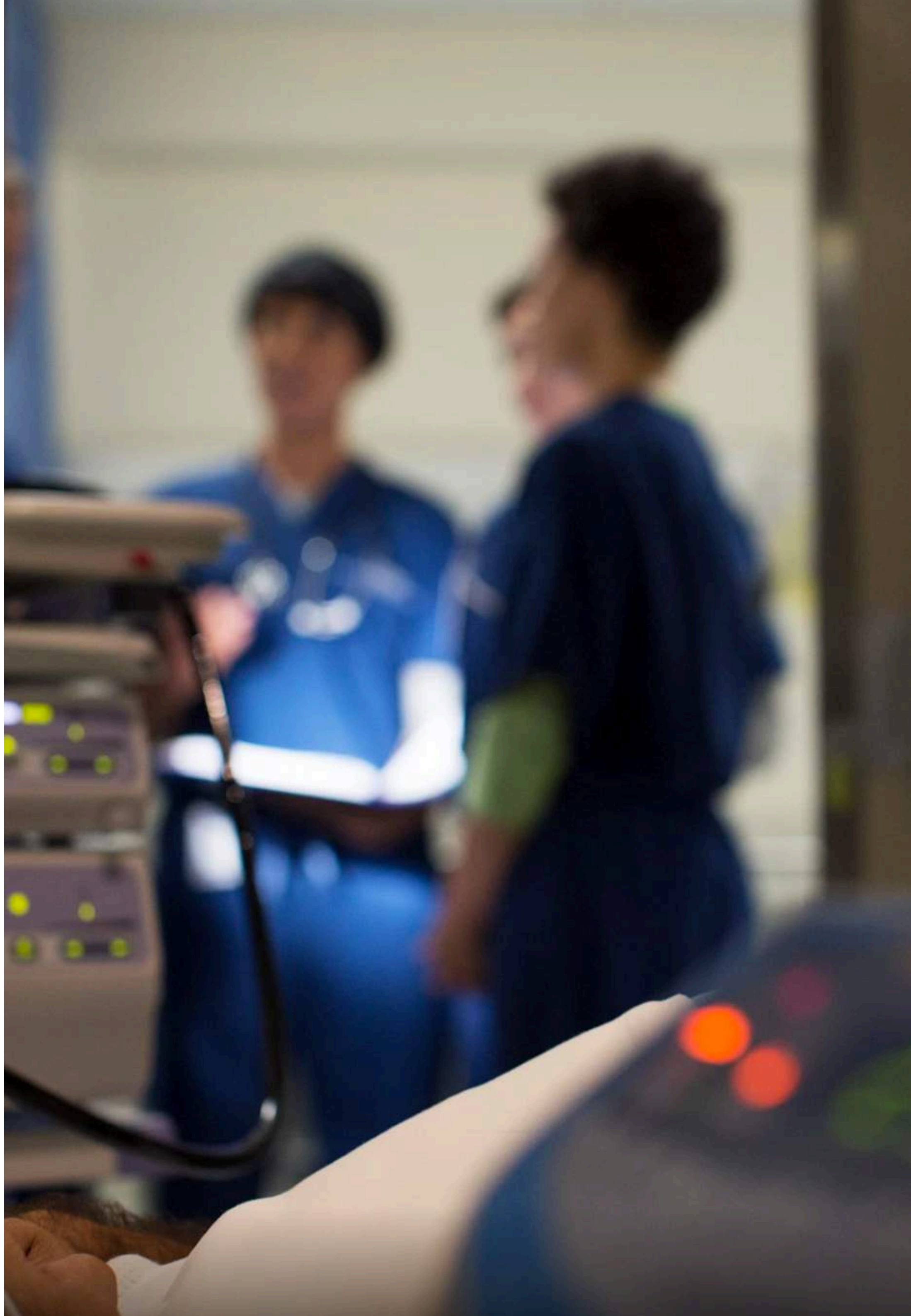
The Critical alarms lab aims to inspire the medical world with an Intensive care that is better designed for all its users. The project will create:

a calmer environment for the patient to recover in;

a less confusing environment for the visitor so that they can fully focus on the patient;

an improved work environment for nurses that cause less alarm fatigue and errors.

The UltiMo's biggest challenge was to cater to the different users. Clinicians and visitors enter a patient box multiple times a day and both have different needs in terms of what is shown on screen. To overcome this challenge, the system keeps track of who is in the room and changes the monitor accordingly. Since the main job of the monitor is to inform the nurse about their patient's vitals, a hierarchy is built in when different types of people are in the patient box. Therefore there was a hierarchy among users. Whenever a clinician walks into the room, even though other people are in the room, the monitor shows the clinician's screen.



1.2 Context

To develop a product it is important to keep the context it will work in. This chapter describes the Intensive Care, the environment in which the monitor would work. Furthermore, this chapter describes the different users of the UltiMo. It shows the three main users, clinicians, visitors and patients and their personas.

1.2.1 The ICU

The Intensive Care is a hospital department for patients in a critical state. Either because they had an accident, a critical surgery or some other condition that requires continuous observation. Each patient has a dedicated nurse that observes them and each nurse works in shifts of 8 hours. The monitoring system notifies the nurses by sounding an alarm, blinking a light on the monitor and sending alarms to the nurses' pagers. Moreover, the patient monitor can be watched from the nurses' ward. A monitors generate very frequent alarms (39-352 alarms per patient, per day)2–9 and that a high proportion are false, defined as not being actionable (over 90% of pediatric intensive care unit2,3 and over 70% of adult intensive care alarms)(Görges M, 2009).

During the night the current Dräger monitors can be set on 'private mode'. The private mode dims the screen slightly and hides the values and alarms(with a simple pop up window showing private mode). However, turning on this mode has to be done manually by the nurse. When nurses enter the patient room, they have to turn it off again. During the day the monitors are not on private mode and show all values and alarms. The patient still needs to recover and often sleep during the day (Delaney, Haren & Lopez, 2015). The monitor and its alarms disturb the patient during this time (Luetz et al., 2016).

Visitors often get anxious by seeing the various values on the screen which they can't understand. Depending on the nurse, they can get an explanation but more often they look online for an answer. Talking to nurses shows that the monitor demands attention from the visitors. So much that often, the visitors are not focussed on the patient anymore, but on the monitor and every little change it makes. They compare values from other days to current values and make conclusions. They might adjust patients positions so that the values seem to be optimal.

1.2.2 Target Group

There are various groups that have a stake in this project. The various stakeholders and their interest can be seen in appendix B. The project focuses mainly on the three main user groups of the patient monitor: the patient, visitors and clinicians. In figure 1.2.1 their persona's are shown.

CLINICIAN

Marieke Jansen
35 Years old
Married
Nurse
Works 6 days a week
Likes to bake

Needs: Receive clear and reliable information about the patient's condition.
Goals: Be there for patients, take care of and comfort them as much as possible.

PATIENT

Lars Faber
40 Years old
Married
2 children
Hospitalized due to a cardiac arrest
Likes to watch football

Needs: Medical equipment which supports life functions. Constant care and monitoring. Calmness and rest.
Goals: Recover and go back to the normal life.

VISITOR

Klara Faber
38 Years old
Married
2 children
Interested in art

Needs: Assurance that the patient is being taken care of. Information regarding patient's recovery.
Goals: Support patient for a recovery.

Figure 1.2.1: User personas

1.3 Starting point

The previous report of Pinch studio included research on various sensors and the context of the project. This research resulted in: a list of requirements which can be seen on page 12; five concepts appendix C; insight into the project context; challenges for the developing phase (chapter 1.5); and a goal, together with a min and max target, to aim for during the project.

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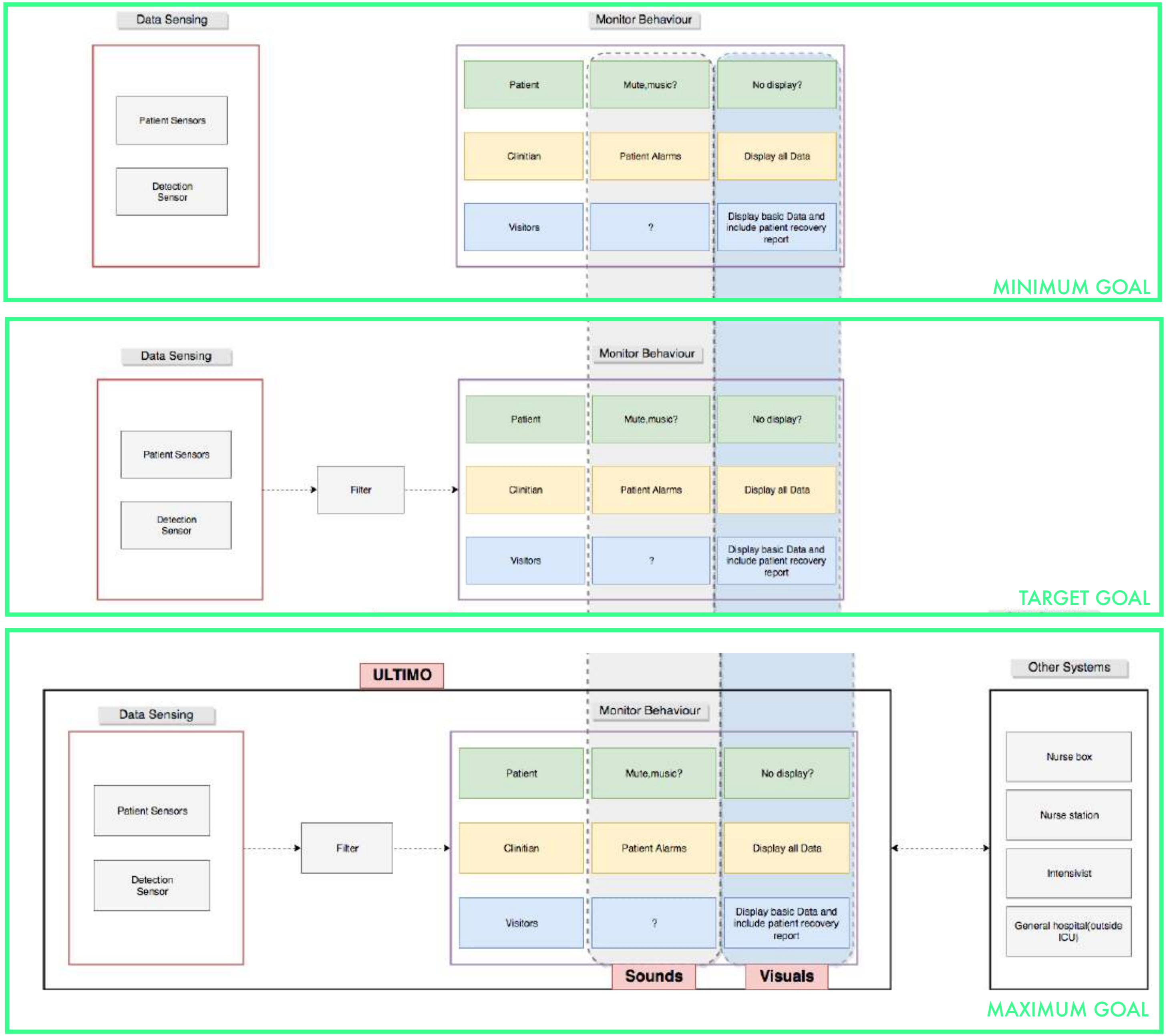

Figure 1.3.1: The different goals for the project as set by Pinch Studio

The research clarified the significance and importance of this project. All stakeholders needs and wants vary greatly and sometimes even contradict each other. Patients require rest and thus no sounds and visuals to disturb them, but clinicians are reliant on the monitor information and sounds(although mostly unnecessary). Furthermore, the limits and possibilities of the medical environment were researched.

The goal of this project was to develop a working prototype. This prototype would include a system of sensors and three screen modes suiting each user(patient, visitor and clinician). Since the screens are changing based on who is in the patient box the sensors need to be able to detect people. The prototype build is set into three stages as seen in Figure 1.3.1 of the goals.

As stated before, the list of requirements can be seen on next chapter on which the various concepts have been tested and the success of the final concepts is weighted on. The five concepts are shown in appendix C. At the beginning of this quarter, we discussed the concepts, how well they would reach our goal and how well we could make the concept. We concluded that one concept was not going to make it. Thus two concepts were eventually combined to fully reach our goal. The two concepts below, Identicam and Beacons, are combined into the final concept, prototype and design that is further developed in this report.

The ultimate goal would have been to have a fully functional system that could almost instantly be implemented and used. However, during the process, there are challenges that come up and we had to work with. Therefore the target goal and the minimum goal that needed to be reached were also stated (Figure 1.3.1). The next chapter will discuss these challenges and the resulting solutions.

1.4 List of Requirements

1. It has to be 100% certain that (important) alarms are heard or seen by someone, in the room or outside by the nurse station or on the pager.

2. The critical alarm (cardiac arrest) should always be heard and shown, no matter what.

3. The monitor should give some feedback that it is functioning correctly, even when the monitor is “sleeping”.

4. When the system does not select the right monitor mode, clinicians should be able to overwrite it.

5. The monitor should adjust its behavior according to who is in the room(Clinician, visitor and none).

6. The system should be able to differentiate between two different groups, visitors and clinicians.

7. The system should keep track of the presence of the different groups in the patient box.

8. The system should have a detection accuracy of over 99.9%.

9. The monitor should work according to FDA regulation standards.

10. The system should not make use of any existing identification/tracking system used in a particular hospital(for example card-system) that might not be used in other hospitals.

11. The system should not require any additional steps to take for the clinicians. (The passive approach is believed to be superior in that it does not put any extra burden on the hospital staff to remember to scan the barcode)

12. The system should not exceed existing monitor pricing by more than 20% when proposed as a complete monitoring system.

13. The system setup should not take more than a day(per room) and be done while any old system is still in use.

14. The monitor part should not take up more space than existing monitors.

Notes:

Requirement 8 and 9 are for the final system that would be integrated in the ICU. Although the current system does not reach the accuracy requirement right now, with further development this can be done. To reach the FDA regulations, the regulations have to be changed. The initial idea of silencing alarms is not possible as of now. The UltiMo is developed to inspire the medical field and encourage them to innovate and make changes. So that in the future the FDA requirements change and a silent ICU is possible.

The current beacons are placed on the identity cards clinicians carry in the Erasmus. Even though most hospitals have clinicians caring identity cards to place the beacon on, this is not necessary. The beacons could be worn stand alone, on something else or be integrated in the pagers.

1.5 Challenges

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During the project, various challenges occurred. Some we could overcome, others we had to work around. The various challenges are stated below together with the solution to resolve them and how it influenced reaching the goals.

Dräger

Unfortunately, it wasn't possible to work with an actual Dräger monitor. There was no possibility to take the monitor apart and alter it since it is highly valuable equipment and Drägers concerns regarding privacy issues. Therefore it was not possible to integrate the project with the current setup of the Intensive Care. To overcome this challenge Pinch studio used another monitor that could be manipulated, namely the raspberry Healthy Pi. The Healthy Pi can be connected to a person to monitor some basic vitals: ECG, SpO2 and temperature. The Healthy Pi could be used to show these values on a laptop screen which could then also be manipulated to show the wanted modes based on who is in the patient room.

Coding

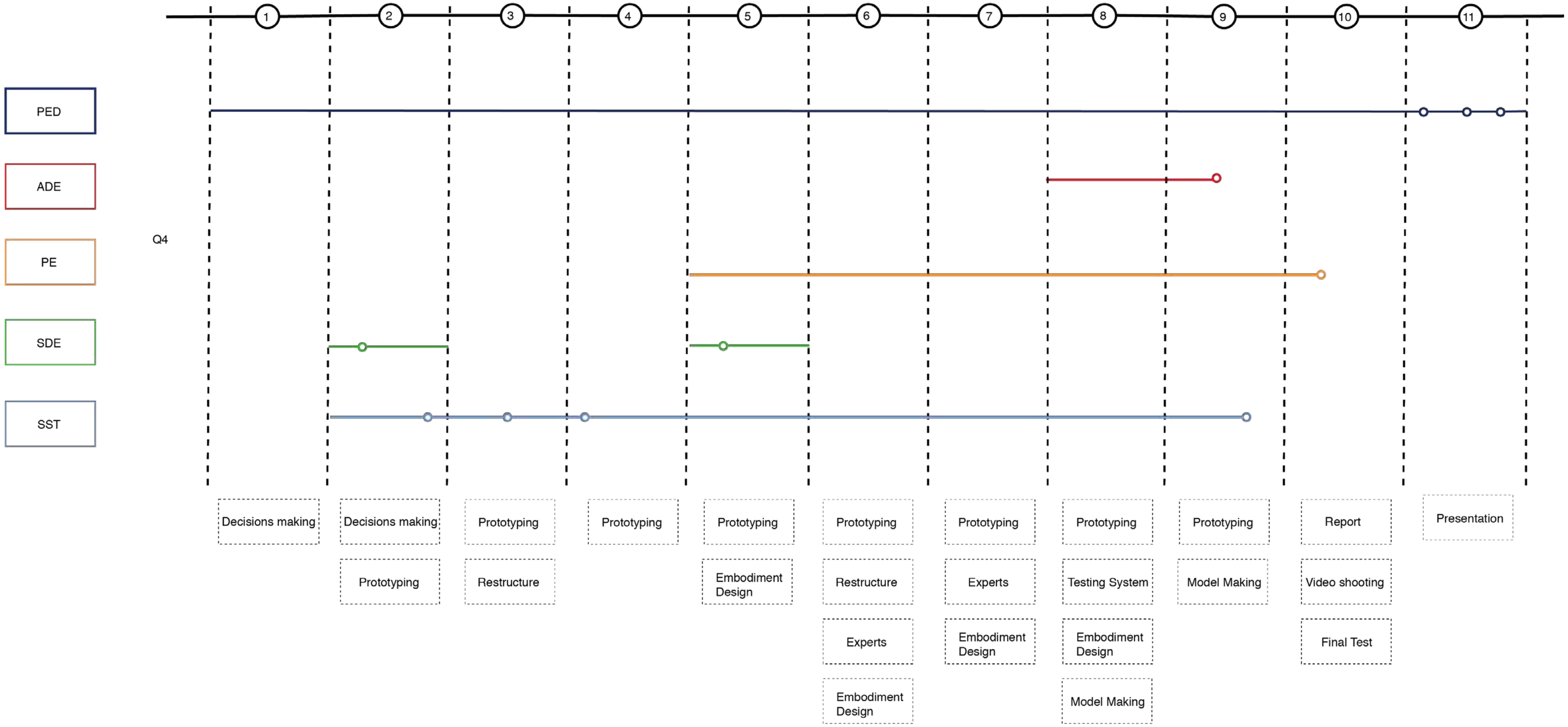
The project includes a lot of coding, to make the image recognition, the beacon scanning and the Healthypi working and working together. Since we are a group of designers, not proficient in coding, the coding part of the prototype proved to be a challenge. Most of the coding has been done by Pinch studio, with help from friends that knew how to code. In the end, a coder provided us with a solution to connect the different parts and enable them to talk to each other. At the end with a little bit of help, we managed to mostly overcome this challenge. However, there are definitely multiple improvements that need to be made before implementing the system(more on this in the chapter 2) and would likely require an experienced software engineer.

Visual Design

This project is focussed on making a working prototype which is based around electronics and software. This left little time to design a physical prototype. However, since a redesign can add toward a convincing proposal and vision time was allocated to do so. The monitor design is the studio's vision of what an intelligent monitor would look like. The monitor is designed in a sleek and intelligent way with calming organic forms meant to differentiate itself from the current 'customary' monitors.

As in any project, there are things you cannot anticipate. Obstacles arise along the way and decisions that can greatly influence the project outcome are need to be made quickly to keep to the schedule. Most challenges have been overcome and some could have gone better or required more time. In the end, the project has met our expectations and is ready to be handed over to the next group. The part reflection will further discuss what went well and could have gone better with this project.

1.6 Plan



The second half of the project starts with discussing the various concepts and how they could be further developed to the final product. Since the project has multiple areas to conform to, the workload will be split among team members with weekly briefings to keep everyone up to date. The final prototype needs to be finished in 9 weeks. Depending on the progress speed of the primary goal(a working prototype) more time will be allocated to other aspects of the product such as monitor design, usage, etc. We aim to have a physical/visual model which looks and feels like it's sophisticated and smart, more than just any other regular monitor currently on the market. This can amplify our vision and the importance of a silent, well-designed ICU. A redesign of various aspects of the monitor is, therefore, be included. However, these redesigns will mainly serve as a preliminary design and will likely require more thorough research. Of course, all this will be done in parallel to the requirements/assignments posed by the expert areas. Lastly, the final report, movie and presentations are made during the final weeks of the project.


Internal
100 %
Filter: ESU
Adult
O2

THE SYSTEM

Various ways to detect people were thought through and tried out. The final decision on which technologies to use in this project was primarily based on two things; fit within the context and complexity of implementation.

The technologies best suited for this context are thus Bluetooth Low Energy(BLE) beacons combined with camera path tracing. The BLE beacons can send out advertisements on regular intervals which can be read by Bluetooth scanners and the camera is used to counting people entering and leaving the patient box.

The design of the Ultimo system assumes the most convenient and user-friendly sensing technologies. Given the context and the task of differentiating between clinicians and visitors, multiple methods are possible to detect the difference between them. For instance, it is possible to force everyone to push one of two buttons when entering and leaving a patient box. One for the visitors and the other one for clinicians. However, this will likely result in many complications: people forget to push a button (because they are in a rush), people push the wrong button, visitors push the clinician button to see more details, etc. Therefore, we take the user out of the detection equation. The system requires a foolproof method of keeping track of who everyone is on its own. The UltiMo works with a counting and detecting method. With this method, the number of people entering and leaving a patient box will be counted. Visitors require no extra tags/cards/devices so that they can not forget them or get confused about it. The clinicians, on the other hand, will carry some sort of identifier. Clinicians are already required to keep their pager and card with them at all times. Something unintrusive that could be attached to this and would not bother the clinicians. By adding something that could be detected, the system could check if the person entered is a clinician. This way the monitor could switch to the right screen.

The development of the sensor system took on a rather iterative approach. As shown in the concepts(Appendix source C) there are many ways to create a system capable of detecting people and identifying them.

Various ways to detect people were thought through and tried out. All of the 7 technologies were researched and some even developed (see Appendix F 'Sensor research'). However most could not be used due to it requiring additional actions for the user, being unreliable/inaccurate, having a possibility of interfering with the equipment or proving to be too complex to develop within the timeframe of this project. The final decision on which technologies to use in this project was primarily based on two things; fit within the context (see requirements page 11) and complexity of implementation.

The technologies best suited for this context are thus Bluetooth Low Energy(BLE) beacons combined with camera path tracing. The BLE beacons can send out advertisements on regular intervals which can be read by Bluetooth scanners and the camera is used to counting people entering and leaving the patient box.

2.1 Hardware

The system requires various components to work properly, this includes; an IP camera, BluetoothLE scanner, beacons, Healthy Pi HAT and a computer running the program(s). In this chapter, all hardware components and their purpose are described. However, the chapter 'Software' will go into further details on the precise behaviour of the components of this project.

2.1.1 IP Camera

The IP camera is built from a Raspberry Pi zero W and a Pi camera. An IP camera is preferred over a wired camera due to cable management complications. The Raspberry Pi is equipped with the motionEye operating system which enables streaming over a local network. This image stream can be viewed from any computer on the same network. The system's software can thus retrieve this image stream and use it for people counting. The chapter software will go over this in more detail. The video feed from the IP camera is shown below (Figure 2.1.1).

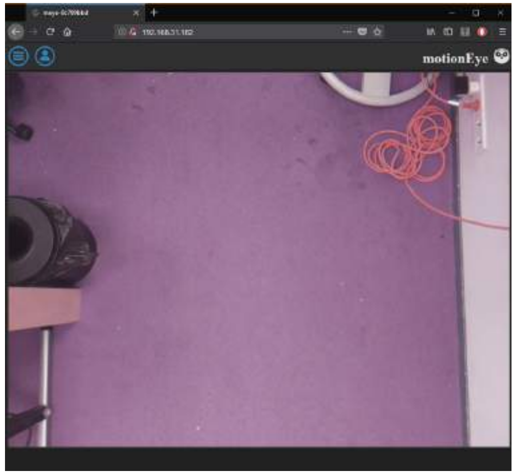


Figure 2.1.1: Video feed from IP Camera

2.1.2 BLE scanner

The monitor will be equipped with a BluetoothLE scanner. As mentioned in the beacons description, these scanners detect nearby beacons and retrieve their advertisement. In this project, a Raspberry Pi 3B is used to scan the beacons. Further development of the UltiMO might require multiple scanners per room to increase accuracy and speed in the system. Then the Bluetooth scanning is not done locally (on the monitor pc) to allow scalability. The Raspberry Pi has the node.js and estimote package installed to not only scan for the beacons but also send the retrieved data to a server.

2.1.3 Beacons

Small estimote™ beacons (Figure 2.1.2) are used for the distinction between clinician and visitors. The hospital's clinicians will all carry their own beacon placed on their ID card. The beacons make use of Bluetooth Low Energy (BLE) to send advertisement containing information on its properties like ID, RSSI, TX-power, etc. These values can be retrieved by BLE scanners which interpret these properties to estimate their distance.

Figure 2.1.2: estimote™ beacons

2.1.4 Healthy Pi HAT

The Healthy Pi HAT is used to read a patient's vitals using sensors. Our system has three screen modes. One of these displays full patient vitals and the Healthy Pi can provide this data real-time. The Healthy Pi comes with an ECG, SpO2 and temperature sensor. The Healthy Pi itself interprets the input from the sensors and can relay them via USB to a PC with software which is able to unpack the data. A picture of Healthy Pi is shown below (Figure 2.1.3).

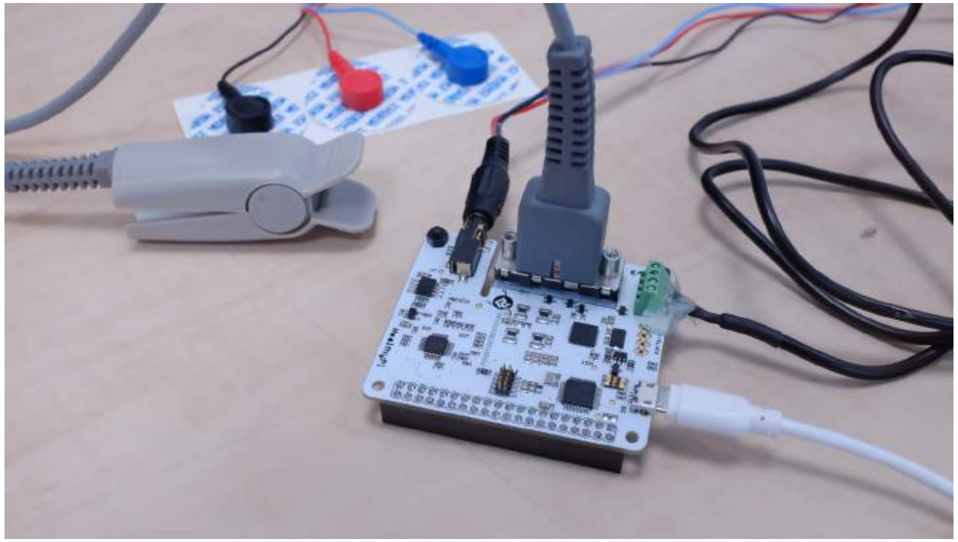


Figure 2.1.3 : Healthy Pi HAT

2.1.5 PC

A large part of the system is managed on a regular laptop. Which is similar to the current ICU Patients monitors (current ICU Patient monitors run on standard Windows PCs). The laptop is used to display the different screen modes, detect people with the camera, run a local host, request beacon data and unpack the HealthyPi data. The higher the performance of the PC the better the system will work since it speeds up computational intensive processes and thus updates rates.

2.2 Logic

The decision on which screen to show is based on input data from the sensors. All logic used in the code can be divided into 3 parts; counting, scanning and displaying logic. This chapter fully focuses on the logic behind the system. The actual coding can be found in the chapter 'software'. This chapter serves as the basis on which the code will run and how all components behave to acquire a sufficient amount of information for a properly working system. At the end of this chapter, the flowchart of the entire system is presented.

2.2.1 Counting

The UltiMo uses a ceiling-mounted camera to count the people entering and leaving the room. The camera provides us with sequential frames which can be analysed to detect shapes (human shapes).

First, several frames are used to establish a background image. This background image is used to differentiate the foreground from the background. When an object stands underneath the camera for a longer period, the shape will be masked and the background reference updates using the entire frame. This is necessary to keep the background 'up-to-date' since room lighting might change and new stationary objects can be placed in the frame. Both need to become part of the background. The flowchart of counting is shown below (Figure 2.2.1).

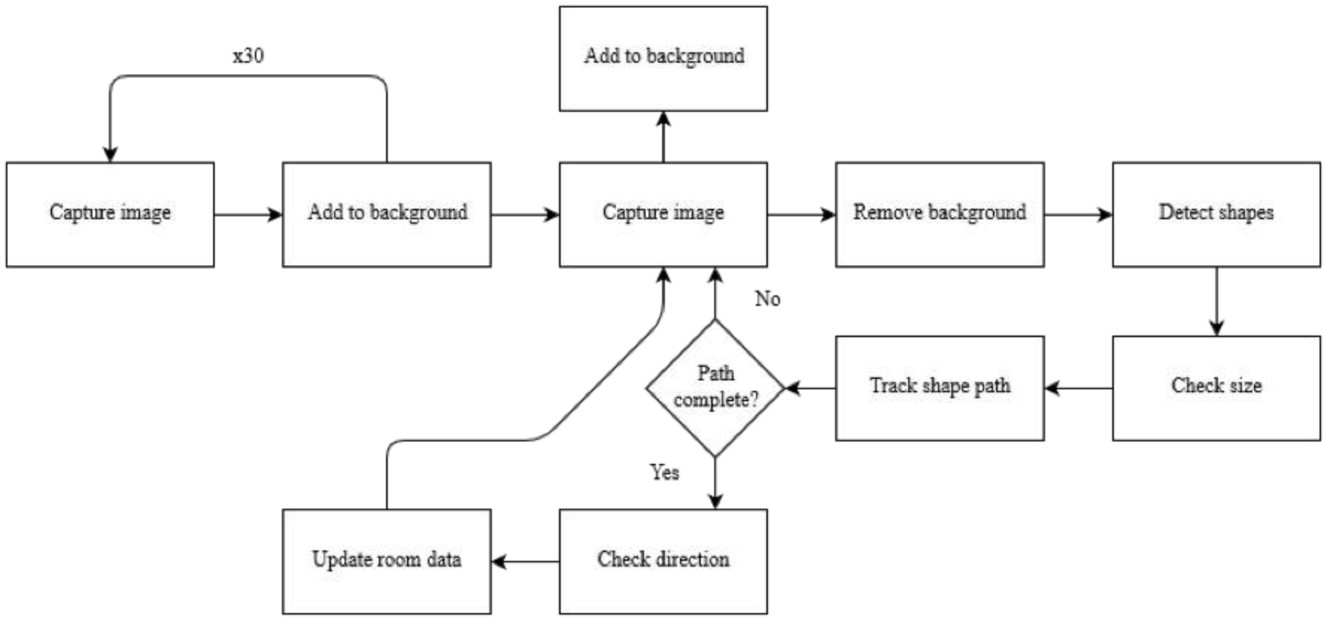


Figure 2.2.1: Counting Logic

2.2.2 Scanning

Compared to the counting logic, the beacon logic is fairly simple. In principle, the beacons are scanned as often as possible inside a continuous loop. Each loop updates the scanned beacon's data and posts this to a local server. Thereby keeping a database of all beacons with their distance. Since there are other Bluetooth devices nearby, the scanner will check if the detected Bluetooth device is of the correct type, prior to updating the data. The loop is shown in Figure 2.2.2.

2.2.3 Screen Logic

The scanning and counting provide data for changing between different screen modes. The screen logic interprets this data and decides what to show using various if statements. Figure 2.2.3 shows this in full detail. Note that beacons have priority over people counting, this ensures that the clinician's screen will always be shown when there is a beacon nearby even when the counting did not detect due to a disconnection.

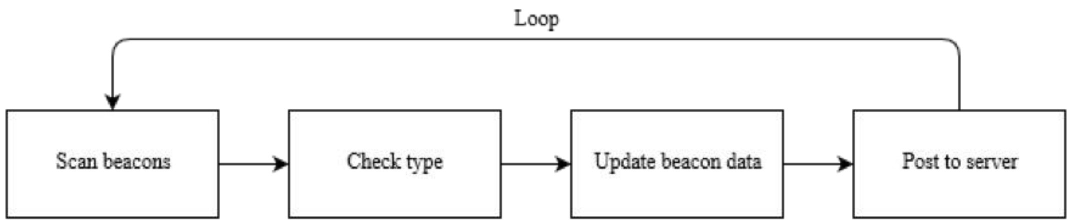


Figure 2.2.2: Scanning

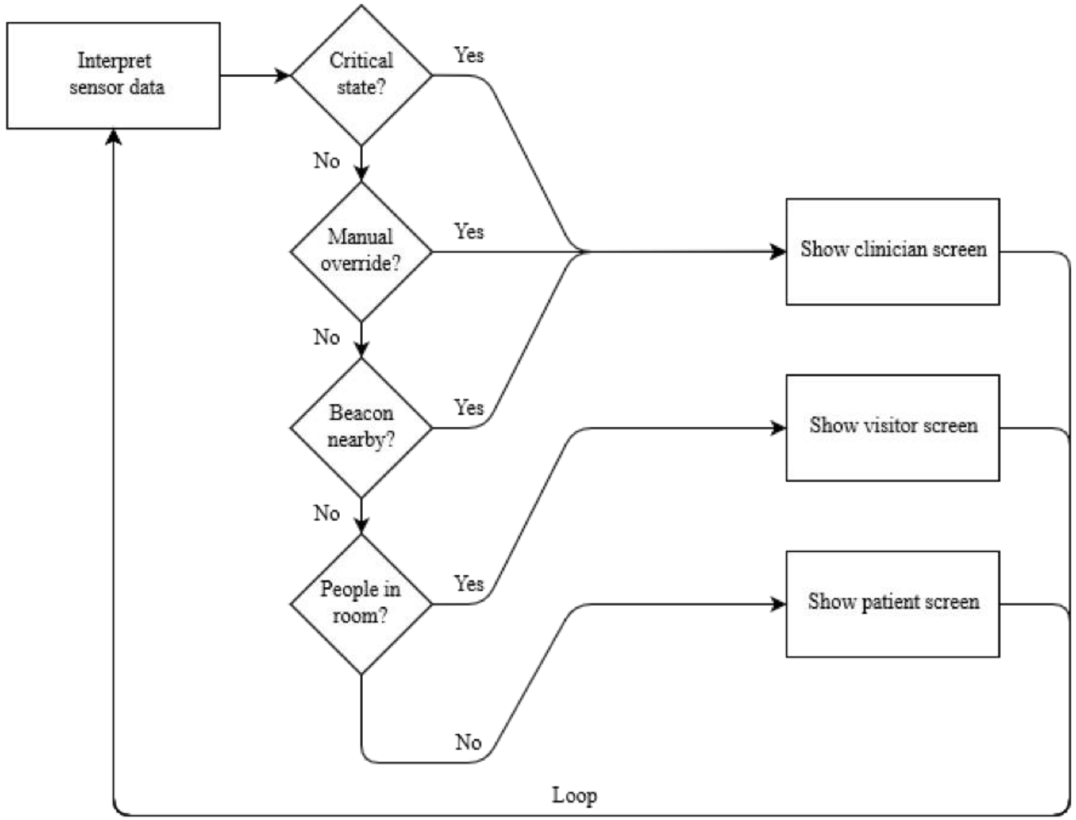


Figure 2.2.3 : Screen Logic

2.2.4 Final

The complete flowchart is illustrated in Figure 2.2.4. Aside from the previously mentioned flowcharts this also includes a quick flow diagram of the patient vitals sensors (Healthy Pi). In the scenario that systems will fail in detecting, the screen should always default to clinician mode (this is not illustrated in the flowchart).

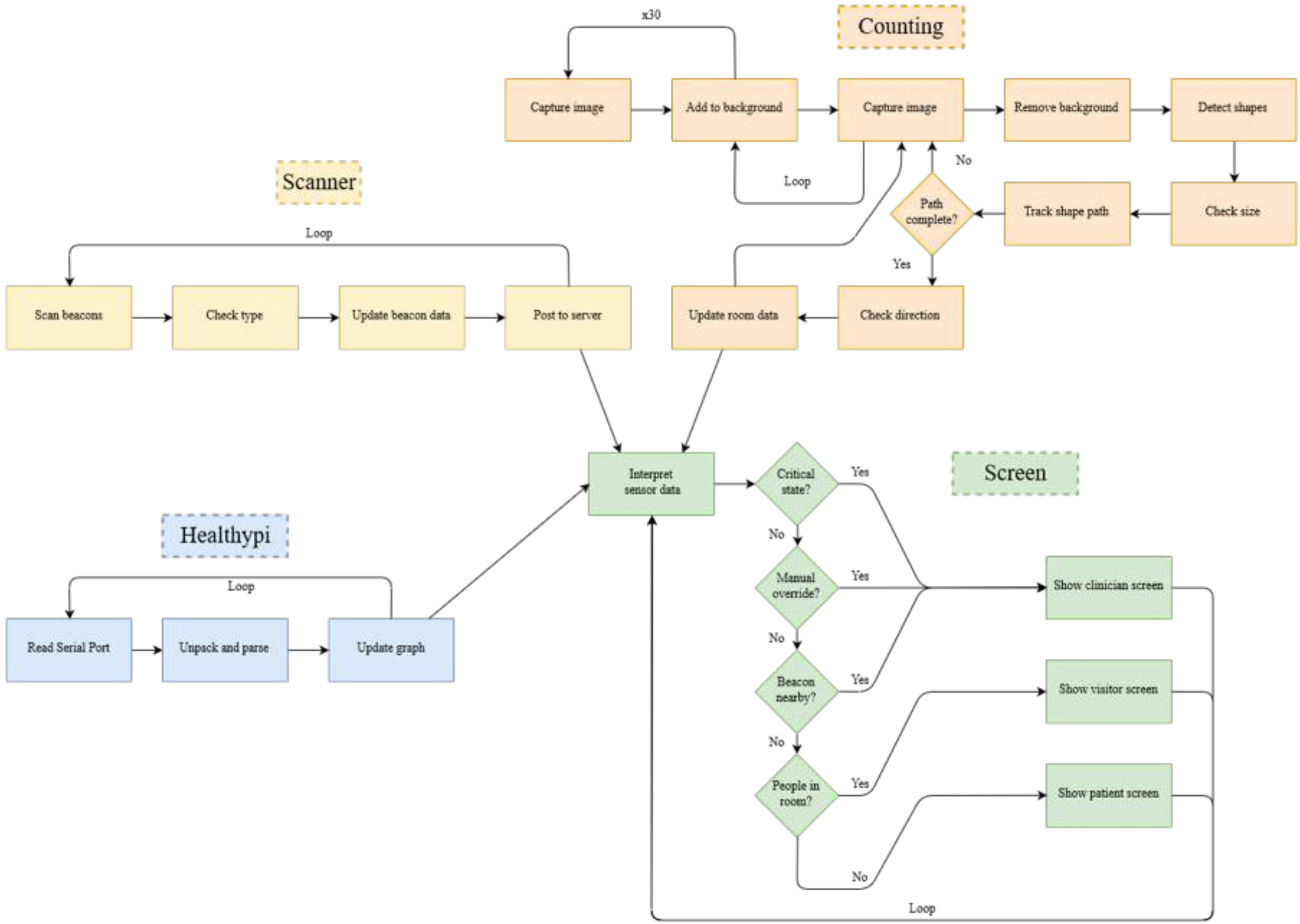


Figure 2.2.4: System Flowchart

2.3 Software

The software is written in both javascript (for hosting, posts and requests) and python 3.6 (data interpretation, logic and GUI). The software is divided into 5 parts: local server, beacon scanning and posting, people detection, Healthy Pi interpreter and screen GUI.

The software runs on both raspbian Linux and windows using javascript and python and will require several packages to be installed in order to work. A list of requirements/packages can be found on page11. The full code can be found in the product package.

2.3.1 Local server

A local server is used to save data about the beacons. Using node.js we initialise a server which listens to the data input and posts it on a localhost. This server is used to display the beacon data. The code can be found in Appendix G. The server also sets a timestamp with every new update of a specific beacon. The past 12 beacon RSSI values are listed in points 0-11 and position 12 shows the average.

```
const HTTP   = require("http");
const URL    = require("url");

let state = {};

function okay(res, data) {
    let dataString = JSON.stringify({
        beacons: data
    });
    let length = Buffer.byteLength(dataString);
    res.writeHead(200, {
        'Access-Control-Allow-Origin'    : '*',
        'Content-Length'                 : length,
        'Content-Type'                   : 'application/json'
    });
    res.end(dataString);
}
const server = HTTP.createServer((req, res) =>
{
    let query = URL.parse(req.url, true).query;
    let id_tmp = Object.getOwnPropertyNames(query);
    let id = String(id_tmp[0]);

    if (query[id] != null) {
        if (state[id] == null){
            state[id] = {};
        }
        //let now = Math.floor(Date.now() / 1000);
        let d = Date.now()
        //let d2 = d.getDate()
        var array = JSON.parse("[" + query[id] + "]");
        state[id].rssi = array;
        state[id].last_update = d;
        return okay(res, "Done.\n");
    }
    return okay(res, state);
});
server.listen(8000, "0.0.0.0");
console.log('Server is running on port 8000');
```

```
D:\IO\Master\AED\Nodes>node server_final.js
Server is running on port 8000
```

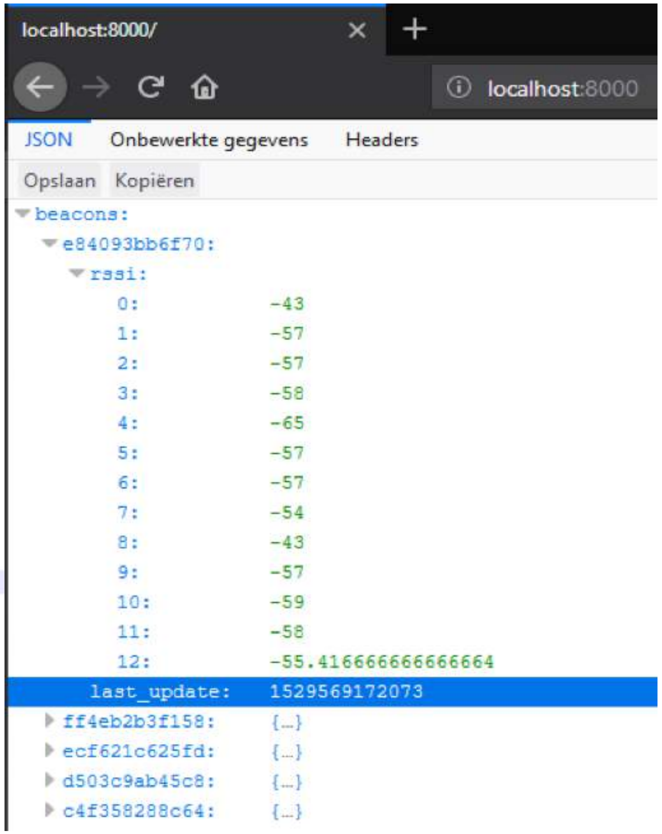


Figure 2.3.1: Local Server

2.3.2 Beacon scanning and posting

The Raspberry Pi scans for beacons using node.js. It continuously loops through all scanned beacons, stores the RSSI value, calculates the average and posts them to the server. The beacon RSSI can be used to estimate the distance from the beacon to the scanner.

```
const noble = require('noble');
const request = require("request");


// Create a Linking object
const BeaconScanner = require('node-beacon-scanner');
const scanner = new BeaconScanner({'noble': noble});

function getSum(total, num) {
    return total + num;
}

var ip_ad = "192.168.31.168";

var beacon ={};
scanner.onadvertisement = (ad) =>{
    if(ad["beaconType"]== "iBeacon"){
        var id = ad["id"];
        var rssi = ad["rssi"];

        if (typeof(beacon[id]) != "undefined"){
            rss_length = beacon[id][0].length;
            beacon[id][0][rss_length] = rssi;

            if(rss_length >=12){
                beacon[id][0].splice(0,1)
                let sum = beacon[id][0].reduce(getSum, 0)
                let avg = sum/12
                beacon[id][1] = [avg]

                try{
                    request.get("http://" + ip_ad + ":8000?"+id+"=" + beacon[id]);
                }
                catch(err){
                console.log("failed");
                self.continue;
                }

                console.log(JSON.stringify({[id] : beacon[id]},null));
            }
        }else{
            beacon[id] = []
            beacon[id][0] = [0];
            beacon[id][0][0] = rssi;
            beacon[id][1] = 0
        }

    }
};

// Start scanning
scanner.startScan().then(() => {
  console.log('Started to scan.');

}).catch((error) => {
  console.error(error);
});
```

```
pi@pinchpi:~/ble-project $ sudo node app.js
Started to scan.
{"ff4eb2b3f158":[[-44,-43,-67,-58,-56,-58,-42,-56,-58,-59,-58,-58],[-54.75]]}
{"ff4eb2b3f158":[[-43,-67,-58,-56,-58,-42,-56,-58,-59,-58,-58,-60],[-56.083333333333336]]}
{"ff4eb2b3f158":[[-67,-58,-56,-58,-42,-56,-58,-59,-58,-58,-60,-49],[-56.583333333333336]]}
{"ecf621c625fd":[[-67,-51,-36,-53,-36,-52,-52,-51,-46,-52,-51,-52],[-49.916666666666664]]}
{"ff4eb2b3f158":[[-58,-56,-58,-42,-56,-58,-59,-58,-58,-60,-49,-59],[-55.916666666666664]]}
{"d503c9ab45c8":[[-65,-67,-65,-74,-64,-66,-65,-52,-65,-67,-56,-66],[-64.33333333333333]]}
{"c4f358288c64":[[-58,-42,-56,-56,-58,-56,-56,-58,-50,-41,-67,-57],[-54.583333333333336]]}
{"ecf621c625fd":[[-51,-36,-53,-36,-52,-52,-51,-46,-52,-51,-52,-51],[-48.583333333333336]]}
```

Figure 2.3.2: Beacon Scanning

2.3.3 People detection

The people detection is done in python using the OpenCV library. The program separates shapes from a background using MOG subtraction. Boundaries are set as a point from which to start tracking the shape's path. During each loop, all shapes are iterated over to check if it is a new shape. In this way, the program is able to sketch the path of a shape throughout multiple frames. If the shape disappears the path is finished and the program checks whether the path was going up or down (Figure 2.3.3). Shapes are filtered based on size to increase accuracy and the path limits can be changed to work properly for any entrance. The shape centre is used to check if the object in the previous frame is the same object as the current one.

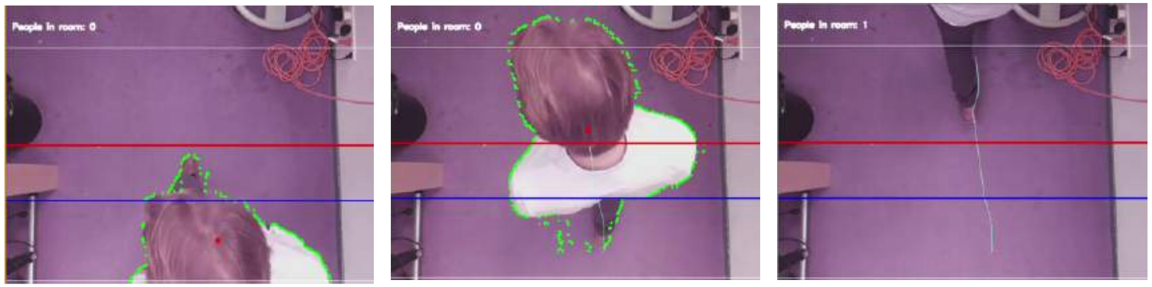


Figure 2.3.3: People Detection

2.3.4 Healthy Pi interpreter

The Healthy Pi is used to simulate patient vitals realtime. These vitals can be sent to a pc (through USB) or Raspberry Pi (as a HAT) in order to plot the sensor data (SpO2, ECG and Temperature). This part explains the software which deals with interpreting this data and displaying it in a graph.

When connecting the Healthy Pi via USB the pc will have to unpack the bits to get the correct values. The packages are sent together with a starting tag to determine the beginning of the array. The package consists of 27 bits, 14 of which correspond to ECG, SpO2 and temperature respectively (4,8,2).

```
usb_data = ser.read_until(terminator=b'\x00\x0b\n') #read the data and save it to usb_data
curr_time = (time.time() - start_time) * 100
print(list(usb_data))
```

```
PROBLEMS 33    OUTPUT    DEBUG CONSOLE    TERMINAL
[250, 20, 0, 2, 0, 0, 0, 0, 0, 172, 160, 99, 246, 97, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 228, 162, 99, 88, 98, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 172, 161, 99, 196, 97, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 172, 159, 99, 183, 97, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 216, 159, 99, 196, 97, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 172, 160, 99, 17, 98, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 40, 163, 99, 1, 98, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 164, 160, 99, 246, 96, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 232, 161, 99, 97, 97, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 136, 167, 99, 205, 97, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
[250, 20, 0, 2, 0, 0, 0, 0, 0, 236, 174, 99, 198, 98, 16, 0, 116, 9, 0, 98, 0, 80, 0, 1, 0, 11, 10]
```

Figure 2.3.4: Healthy Pi interpreter

These bits are stored in arrays in order to plot the sensor lines in a similar way to current monitors. The matplotlib animation function is used to animate the functions continuously. Figure 13 shows a sample plot of the measured SpO2 data. The Healthy Pi interpreter code is merged with the GUI code in order to display the information.

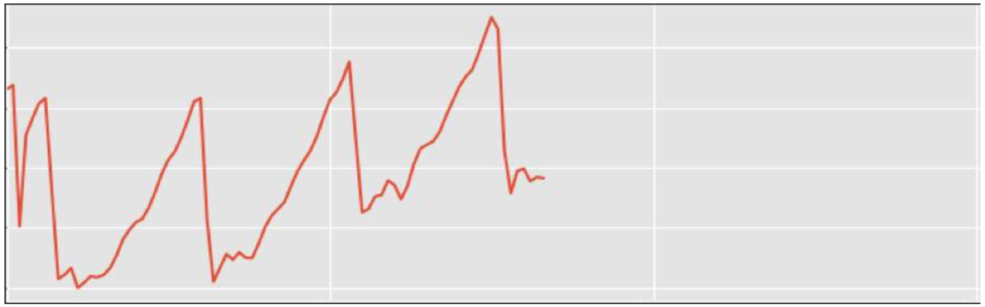


Figure 2.3.5:Plotted SpO2 data

2.3.5 Screen GUI

For the screen, GUI python makes use of the Tkinter package. This package allows the creation of windows inside python. The screen GUI is required to show screens with different content based on the sensor data. The GUI contains 3 windows displaying a different image(figure 2.3.6). Upon start, the windows are opened and a function is called to update the graphs and sensor data. This part of the code is the main program which will retrieve all other data. Depending on the data received it will show one of three screens. As seen in figure 2.3.6 the logic is slightly simplified than previously explained. The program is not yet able to deduce a critical state from the healthypi input, which would be necessary for the final implementation. Furthermore, for both the patient and visitor mode a button is placed on the screen to switch to clinician mode manually.

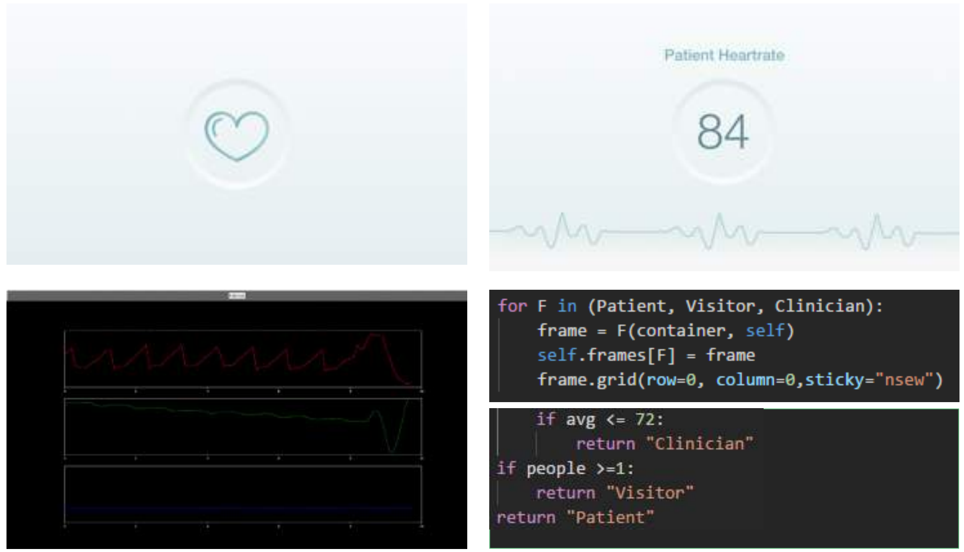


Figure 2.3.6:Screem GUI

2.4 System usage

This chapter covers the steps required to make use of the current system. Aside from downloading the code, installing compilers/packages and collecting the hardware, several parameters need to be adjusted inside the code files in order for the system to work (make sure all devices are on the same network). These changes will happen mostly inside the camera detection and ble-scanner files.

Step 1: Set up the local server.

Open command prompt and type 'ipconfig' and press enter. The terminal will show your pc local ip address which is needed to retrieve data from. Then run the 'server.js' file in the directory where the file is located by typing 'node server.js'. If successful the terminal should show 'Server is running on port 8000'. You can also check this by typing in your local IP address in a web browser followed by ':8000'. The browser should show an empty list of beacons. You can change the server port by changing server.listen '8000' to something else.

Step 2: Scan for beacons

Power up the Raspberry Pi scanner and locate the beacon_scanner.js file. Open this file in a text editor. Change the 'ip_ad' variable to the IP of the localhost. Save the file. Open the linux terminal and navigate to the file directory. Type 'sudo node beacon_scanner.js' and press enter. The terminal should print "Started to scan" And will display a list of beacons with their rssi values.

Step 3: Start IP cam.

Power up the Raspberry Pi camera that has motionEye installed. Check your wifi admin page to determine the camera's IP address. Enter the camera's IP address in your browser. Inside this screen you can setup some camera properties. Search for the port host and make sure the camera frame rate is set to its highest the quality can be around 600x600. Enter the IP address once again followed by a colon and the port number. Only the camera image should be shown on screen

Step 4 Calibrate camera detection.

Power up the Raspberry Pi camera that has motionEye installed. Check your wifi admin page to determine the camera's IP address. Enter the camera's IP address in your browser. Inside this screen you can setup some camera properties. Search for the port host and make sure the camera frame rate is set to its highest the quality can be around 600x600. Enter the IP address once again followed by a colon and the port number. Only the camera image should be shown on screen

Step 5: Setup Healthy Pi and GUI.

Open the file 'GUI.py' and connect the Healthy Pi to the computer via USB. Check the which serial port the Healthy Pi is connected to and change the 'ser' variable to the correct port. Make sure all PhotoImages are pointed to the correct folder and file. When using the Healthy Pi an error might occur stating denied access to it, this is often solved by unplugging and replugging the USB cable. In the switch_screen_logic() function you can change the avg variable to in- or decrease the range at which the beacons are detected.

Step 6: Run the program.

If everything is setup correctly the program can be run. The camera should detect people going in and out and the beacons will be detected. The screens will change accordingly when visitors or clinicians are in the room.

THE DESIGN

UltiMo, as a system consists of a sensor-panel, camera, beacons, PC, mounting basket, standt, and a display. The inspiration for the design comes from a vision of a Silent ICU where the patient experiences a peaceful recovery. The design has started with sketching the main component of the system, the PC where all the processing takes place. As the novelty of the product is that it senses the people present in the patient box and reacts accordingly, it was intended to make the PC look intelligent.

3.1 Iterative design process of the monitor

UltiMo, as a system consists of a sensor-panel, camera, beacons, PC, mounting basket, standt, and a display. The inspiration for the design comes from a vision of a Silent ICU where the patient experiences a peaceful recovery. The design has started with sketching the main component of the system, the PC where all the processing takes place. As the novelty of the product is that it senses the people present in the patient box and reacts accordingly, it was intended to make the PC look intelligent.

Firstly it was decided to incorporate the PC inside the monitor display by making the monitor more powerful. This would eliminate the number of components on the stand. But after few iterations it was realised that the computing module has to be portable. This is to move the computer to bedside when patient is being shifted from one place to the other. So, the PC has been shifted to a separate component which can be attached to the main display as well as patient bed. In the later iterations the PC design has evolved into a PC and a holding basket. The basket extends to the top of PC to act as a mounting for display. This mounting part of the display had several iterations before reaching the final shape. Initially it was intended to design the neck part as a continuous pipe of roll stand. After iterating with the basket design, the the neck design has been evolved as an integral part of the basket that is bearing the display on top of it to show whatever the PC intends to show. The monitor design has been planned not disrupt the current design much except from enlarging the display and making it slim. After deciding on the main parts like PC and monitor, there were few iterations on cable management. In ICU, several sensor cables are attached to the patient. These cables are connected to processing unit. So incorporating these cable connectors into the PC design has spoiled the beauty of PC. After couple of brainstormings, the sensor cables have been eliminated by introducing a sensor panel with one single cable.

The system design resulted in a system using a camera for people detection and beacon for identification. Since the camera needs to record people entering exiting the patient box, it needs to be placed near the entrance, facing downwards. Few iterations of camera mounting were performed by mounting the camera to the wall and ceiling.

First, after observing different ICU interiors, it was concluded that not all the ICU have the patient boxes isolated with walls. In such cases, it would be difficult to mount the camera to the entrance wall. So the mounting has been modified to attach it to the ceiling. Secondly, the height of the camera is constrained to 25 millimeters.

Moreover, the beacons will be attached to clinicians, so that the PC is able to detect their presence. There were couple of concepts to attach beacons to the clinicians. Including some of which attached the beacons to the cloths of the clinician in different places. Another one, the final one, attached the beacon to the identity cards of clinicians. This last one was chosen as the final design. This was chosen since clinicians carry the card along with them at all times, thus carrying the beacons with them at all times.

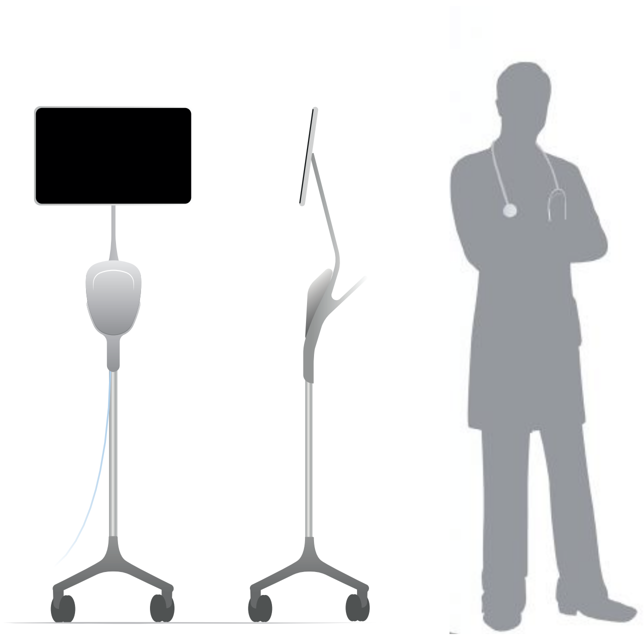
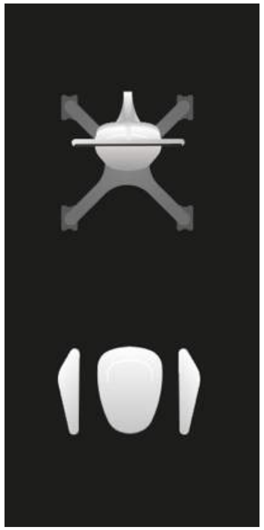


Figure 3.1.1 Ergonomics size

3.2 The PC

The PC is the brain of the entire system. Here all the processing takes place. The PC processes the data received from the sensor panel, camera and scans the beacons. Based on the logic, the PC controls the monitor to switch between the display modes. The PC has been designed ergonomically to move it from one place to other. This PC is mounted on a basket-like structure which is attached either to a roll stand or to an ICU ceiling pendant. The mounting basket consists of two parts, PC holder and neck. PC holder is designed to look like it is embosom the PC and holds it all around. When the PC is placed in the basket, the data transfer takes place from the contact pins on the back of PC to the basket. The roll stand is connected to two external cables, one for the power supply and the other for the hospital network. These cables are routed internally into the basket. Through the contact pins, the data transfer takes place from PC to the hospital network and to the monitor. When the PC is taken off the basket, the PC is disconnected from hospital network and monitor display. Although the PC is disconnected PC keeps monitoring the vitals internally.

The shape is using an arc as the main motive in the form. The front view of the PC is a rotated triangle with rounded corners and tension on the lines. This shape was chosen based on the criteria of a novel and amicable look for the medical device. The morphological chart (Figure 3.1.3) was made to establish the proportion of the triangle and the radius of the corners. The stand was designed to create a well-balanced monitor based on the 2D shape of the PC. The current straight form of a stand looks traditional and plain.



In order to embrace the feeling of novelty and innovation, the neck of the stand is bent in the side view. Front, back, side and top projections (Figure 3.1.2) were made as a base for the CAD modelling. From the 2D shapes, the 3D model was created. Smooth transitions of the surfaces are coherent with organic aesthetic which represents harmony and friendliness. Soft forms are balanced out with a sharp edges which results from the connection of two surfaces. This tension softly despairs and melt with the form. These characteristics are important in perceiving the medical device to built a trust between it and a patient.

Figure 3.1.2 Projection view of the PC

Figure 3.1.3 Morphological chart

3.3 Display

The intention of the monitor design is to make it look intelligent and futuristic. For the same reason, the screen to body ratio has been increased to 97%. The display is a 24 inch LED display with touch screen and pressure sensitive buttons. Pressure sensitive buttons have been integrated underneath the infinity screen by eliminating the tactile buttons that consume bezel space. Those on screen pressure sensitive buttons are for manual override to clinician mode. Secondly, the scroll wheel has been redesigned and repositioned. The new scroll wheel is integrated with the screen profile on the top left corner. The placement of the scroll wheel has been chosen ergonomically to make it easier to reach and interact. The back surface of the monitor follows the front with similar glass. This makes the monitor look sophisticated. The mounting has been designed to facilitate 3 axis rotation of the display. The ball joint lets the monitor rotate about 120 degrees in Y and Z axes and 360 degrees in X axis. To reduce chaos, the cables have been routed internally through the ball joint.

3.4 Sensor panel

All patient sensors are connected to the monitor via the sensor panel. Sensors go from the patient to the sensor panel mounted on the patient bed. One cable goes from the sensor panel to the monitor. These sensors include: ECG sensors to measure the heartbeat; blood pressure sensors that measure the blood pressure from three parts of the body; pulse oximeter to measure the oxygen saturation in the blood; temperature sensor. The panel acts as a collector of all the sensors enabling the use of one cable. This single cable is always connected to the PC even during transport.

If a particular sensor is not necessary, it can simply be unplugged from the sensor panel without touching the PC. Thus the sensor panel acts as cable management, allowing shorter sensor cables. Additionally, this cable management provides a clear view of the room, instead of the current messy one.

The sensor panel follows the same form-language as the camera. The housing part is mounted on the bed to hold the panel. Patient vital sensors are connected to the side while the main cable goes from the bottom. Coloured stripes go from the socket to the front surface of the panel. This results in the clinicians still being able to distinguish each sensor when facing the panel from the front.

3.5 Camera

A camera equipped with a Raspberry Pi zero is mounted near the entrance to capture every event of people entering and exiting the room. This data is analysed by image processing software to recognise the human movement and understand if a person has entered or exited the patient room. The PC will further process this data to take the decision in display behaviour.

The camera is designed to be mounted on the ceiling to get a clear image of the entire entrance. The camera is built in such a way that it can easily be mounted to the ceiling by using a slide and lock mechanism. A soft and rounded shape with clean colour help reduces the feeling of being spied on. The shape language is also designed to be coherent with the monitor design. The upper part along with PCB panel and camera can be easily slid out for future maintenance.

3.6 Beacons & card

The beacons play an important role in differentiating between visitors and clinicians. Beacons are small Bluetooth low energy stickers that send packets of data every few milliseconds. These stickers are made up of silicon with inbuilt battery. Each of these beacons lasts for a year and cannot be reused. Every beacon has its own identity and advertises the data accordingly. Scanning these packets of advertisements, a scanner can recognise a particular beacon and its distance from the monitor. These beacons are attached to every clinician's identity card. The beacons are designed to look professional but also fashionable at the same time with different colours.

The same form language with the PC design is used on the beacons. It is cut from the original shape of the PC from one side and obtains the characteristic surface connection. Silicone is used for moulding the final prototype, it gives a matt texture and a soft touch to the product. Light colours with low saturation and high brightness were chosen to match the organic shape and make the beacons look friendlier while at the same time keeping the clean medical feeling.

3.7 Cost

Compared to the current monitor, ULTIMO includes an additional camera, beacon and a beacon scanner. But the ULTIMO can be introduced into an ICU in two ways. Either converting the current monitor into ULTIMO with a minimal upgrade or developing the brand new ULTIMO monitor.

In the first case, the PC that makes the monitor an intelligent monitor is just a regular PC with a firmware upgrade. In order to make an existing patient monitor into an ULTIMO, the pricing includes the beacon and camera at its least. Typically the beacons cost around €8 EUR including the production and material cost. To make the beacons carryable, a customised identity card has been made. Thus the whole set of beacon with identity card will cost around €10 each. Secondly, the camera includes a PCB, a camera, an enclosure along with a power cable. Thus the whole set of camera costs around 50 to 60 euros including the production and material cost.

Secondly, in order to introduce the ULTIMO monitor with an intelligent looking design it takes quite an effort and resources. The re-design and development of PC makes a great difference in the pricing compared to the current product. Further, the neck part, which needs to be manufactured in metal contributes as well to a huge difference in pricing. Lastly the monitor which has been designed to be slimmer and sophisticated with infinity display adds up to a great amount due to its enlarged size. Due to few uncertainties in materials and production process, it is difficult to make an estimate of the costing for the entire system. But making an educated guess of the approximate pricing of ULTIMO, it can be termed as 150% of cost to the current system.

3.8 Design and research of the screen (PE)

To determine what to show in the visitor mode, a separate research is conducted. As described by the nurses, the current patient monitor caught a lot of attention of visitors. They were "becoming focused on the monitors and asking very specific questions while paying little attention to their loved ones in the bed" (Farrell et al, 2005). Pinch studio aims to inform visitors without causing anxiety and an overwhelmed feeling. This is done by making a draft version of a more user-friendly interface with less and easier to understand vital information. A first step to prepare for the study, an informal interview with 6 nurses was conducted at Erasmus MC. Eight display proposals were made and were used as the starting point of the discussion. Based on the clinicians' point of view 6 displays were chosen and improved for further research. However, there are still some uncertainties that are hard to determine. Therefore there was a research conducted with the research question stated as: "How can a display be designed to both inform and calm a visitor in both a stable situation or when something is happening to the patient."

After the pilot test with 4 participants, the study method was determined. The final research was conducted with 12 participants using both qualitative and quantitative methods. Participants were confronted with 2 examples of the display content of the current ICU monitor and 6 proposals of the new ones (Figure 3.7.1). To process the quantitative results, Friedman's two-way method was used to test the assumptions for each question. To process the qualitative results, the information was organised by presented display and question.

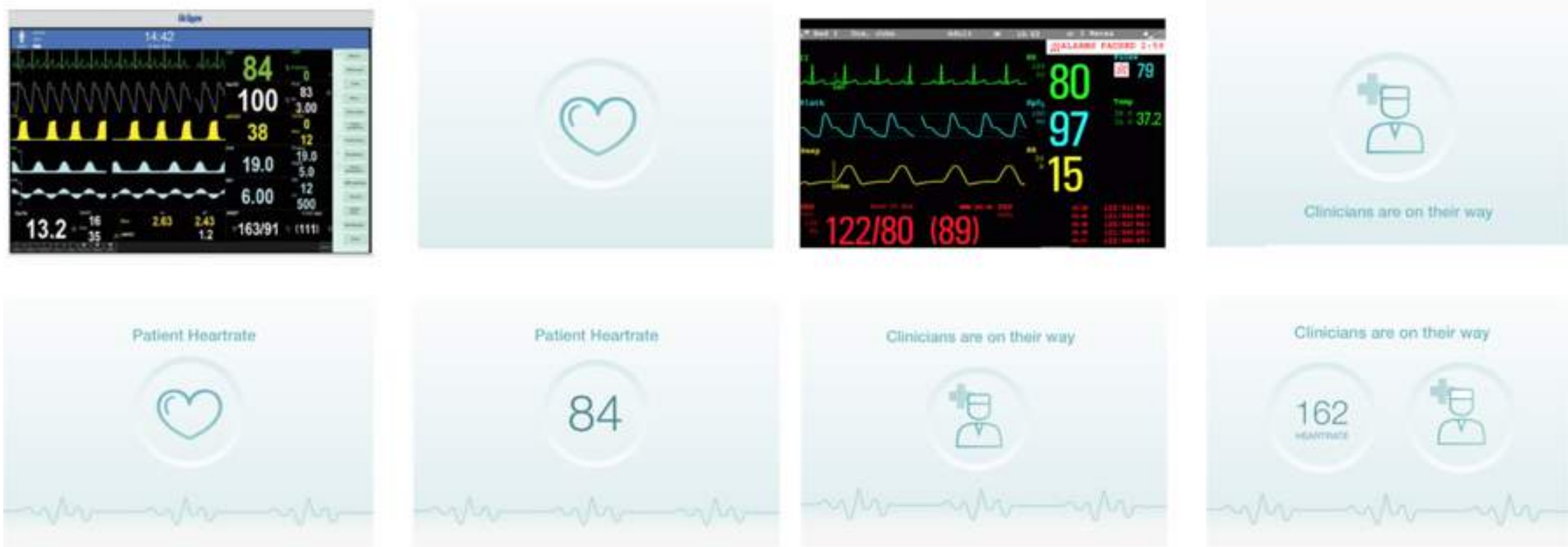


Figure 3.7.1 Displays using for test

Instead of generating a solid conclusion, the research provided insights into the diversity of the participants' opinion and the reasoning behind them. The results provided a guideline about what can be changed in the visitor mode of the monitor display. In general, the new display with text and graphs performed well in terms of informing and calming visitors. Showing only one understandable parameter with number and graph instead of showing the full data makes the monitor much easier to understand and reduces the overwhelming feeling. Explaining the current situation with text gives a clear indication of patient status and essential medical procedure. This gives the message that the situation is under control. They felt thankful by new displays because of the feeling that the information was presented to them. During the emergency status, they felt thankful to know that clinicians are coming. These elements are kept in the final design.

Light and delightful colour gave the display a peaceful look and made it look calmer. However, the colour used for an emergency situation needs to be carefully chosen. Some participants related patient status to used colours, therefore using the same colour for both stable status and emergency status can be very confusing. The final design used a neutral blue which is different from the stable status to clearly indicate that the situation is changing without causing panic.

A drawback of the new display is that reducing the shown parameters and simplifying the layout made the monitor look less reliable than current ones according to visitors. The old familiar monitor screen was valued as reliable because it looks professional and typical (many graphs, numbers). People naturally expect the medical equipment to have a technical look. In order to enhance the reliability, the final design added more medical elements inherited from the current displays.

The final design (Figure 3.7.2) managed to keep the professional feeling of the medical device, while at the same time it gives the visitors clear information without causing anxiety. The display was combined with monitor design and software system and ready for final prototyping.

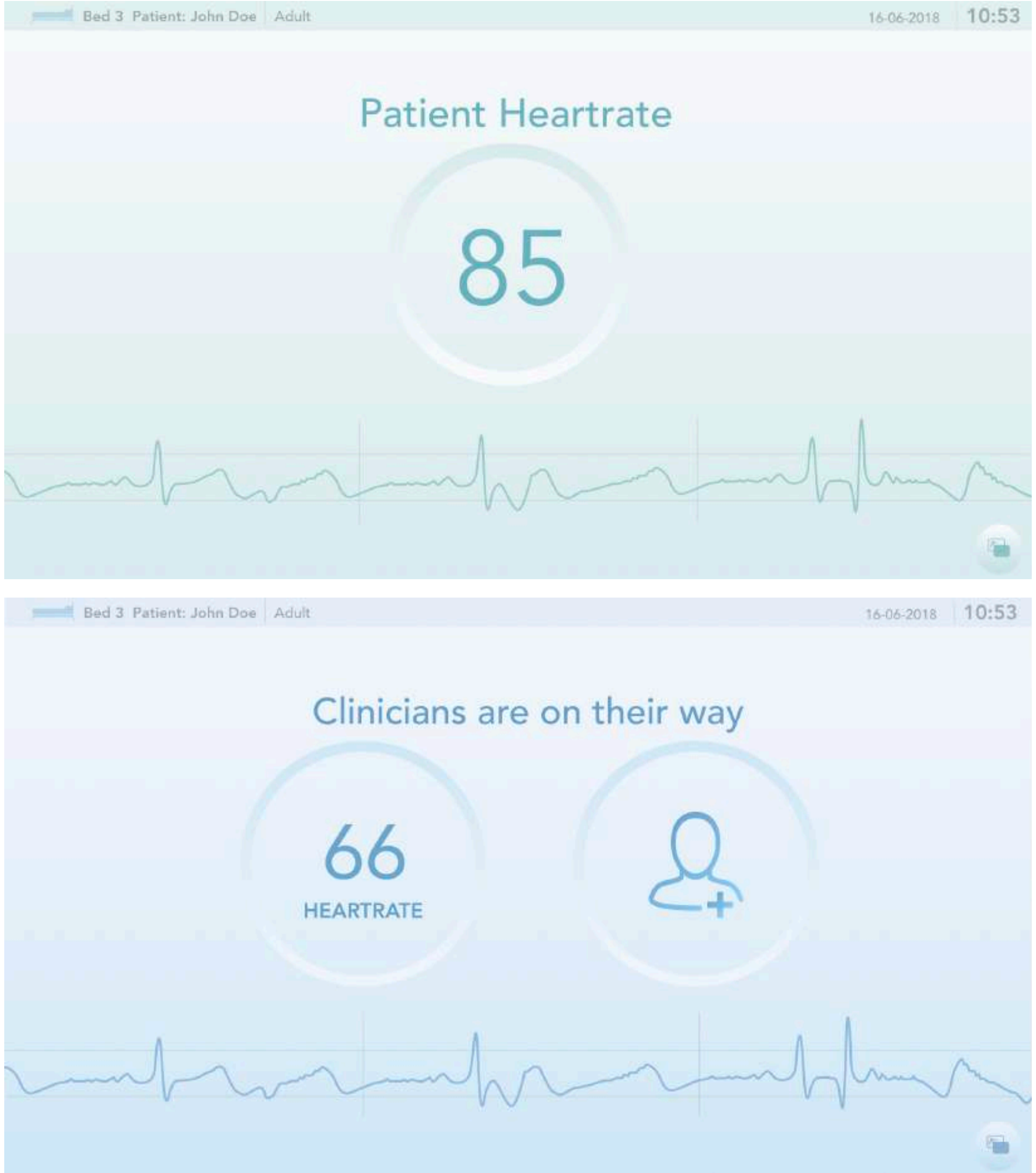


Figure 3.7.2 Final Design

PROTOTYPING

During the second quarter of the project, Pinch studio got their hands dirty. A lot of prototypes were made of software, beacons, and the monitor.

During the second quarter of the project, Pinch studio got their hands dirty. A lot of prototypes were made. During the development of the software, small parts were developed separately to test their workings. In this way, little pieces of code were made which could be stitched together into one. At some points, the code would not be developed further due to it becoming too complicated or slow and thus unusable. For example with stereo vision, cameras had to be calibrated very precisely in order to create a depth map but this eventually did not work out perfectly(which is required for it to work). It also took a lot of time to compute a depth map from two images which were not ideal. Each one is their own little prototype. After it worked, it could be further developed and put together with other working parts. Working in this iterative way, it is easier to build the system. When the whole system is built before a test, it is fairly hard to figure out what exactly is wrong. By testing the various part and making sure small parts work in itself, the parts where an error might occurs is limited and easily detected.

Using the small parts to test also resulted in the iterative process. Seeing that some parts didn't work and altering them didn't help, helped to change the process and look for another solution early on in the design. Especially tracing the movement of people proved to be difficult and various iterations have been made until we landed on the final solution. Below are various pictures of earlier concepts and iterations of this system.

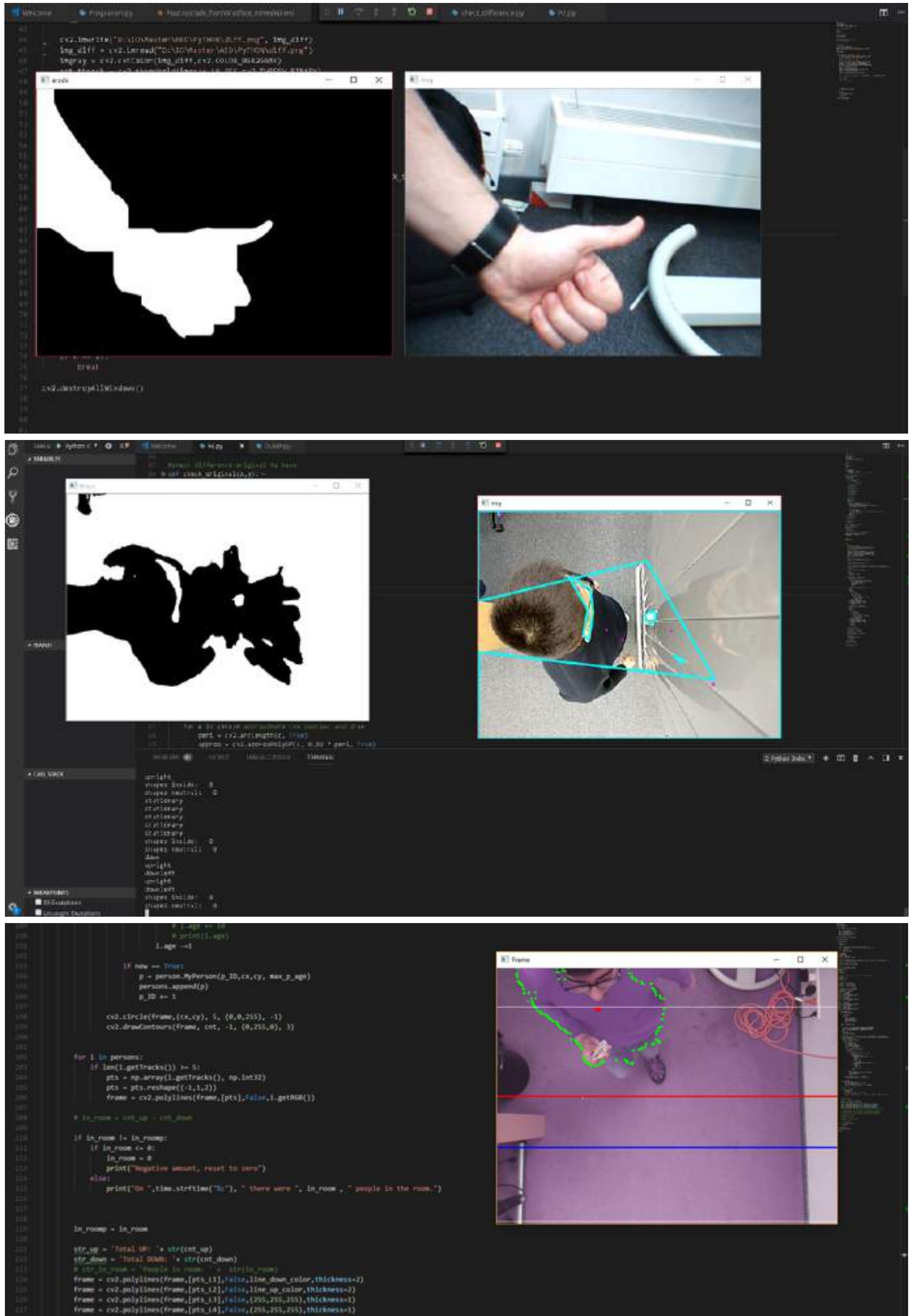


Figure 4.1.1: Earlier concepts and iterations of the system

Furthermore, various prototypes have been made of the beacons. At first estimote beacons were used but later on, custom-made beacons, designed based on the monitor, took their place. These beacons were made from silicon using a thermoformed mould. Not only the beacon itself was designed, the card it is placed on got a design as well. This design is shown in Figure 4.1.4 and has been printed on plastic cards to represent the clinician's identity cards. During the creation of the final prototype of silicone, some errors occurred. At first, the silicone wouldn’t set inside the mould. Later starch was added along with food colouring. This not only allowed the use of custom colours but also started the curing process of the silicone. Another difficulty with the silicone was that it was hard to stick to the cards. This is due to the fact that almost nothing sticks to the silicone. In the end, silicone was used to stick the beacons to the cards.

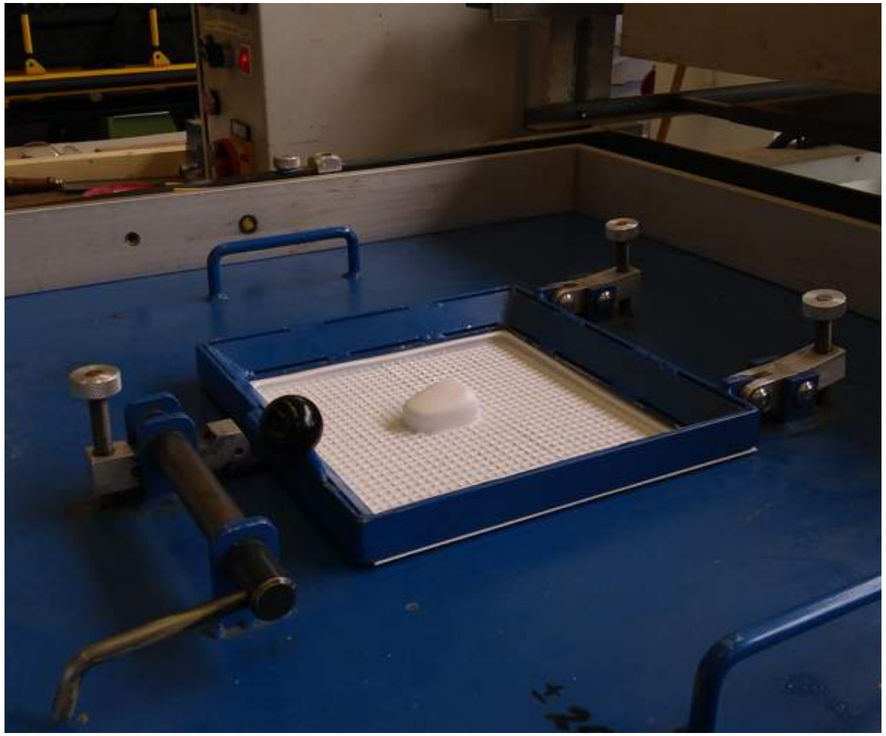


Figure 4.1.2: Hot pressing silicon mold

Figure 4.1.3: Molding and cutting silicon model

Figure 4.1.4: Clinician card design

Lastly, during the design of the monitor, sketching and 3d modelling was initially used to brainstorm the design. After the brainstorm session on the monitor design, 3D renders were made. The design was discussed based on renders and this process repeated until a final design was established.

After the design reached its final state, physical models were made to see the product shape in real life. At first foam models that were CNC milled were made, but 3D printing proved to be a more suitable method.

Figure 4.1.5: Brainstorming on monitor design

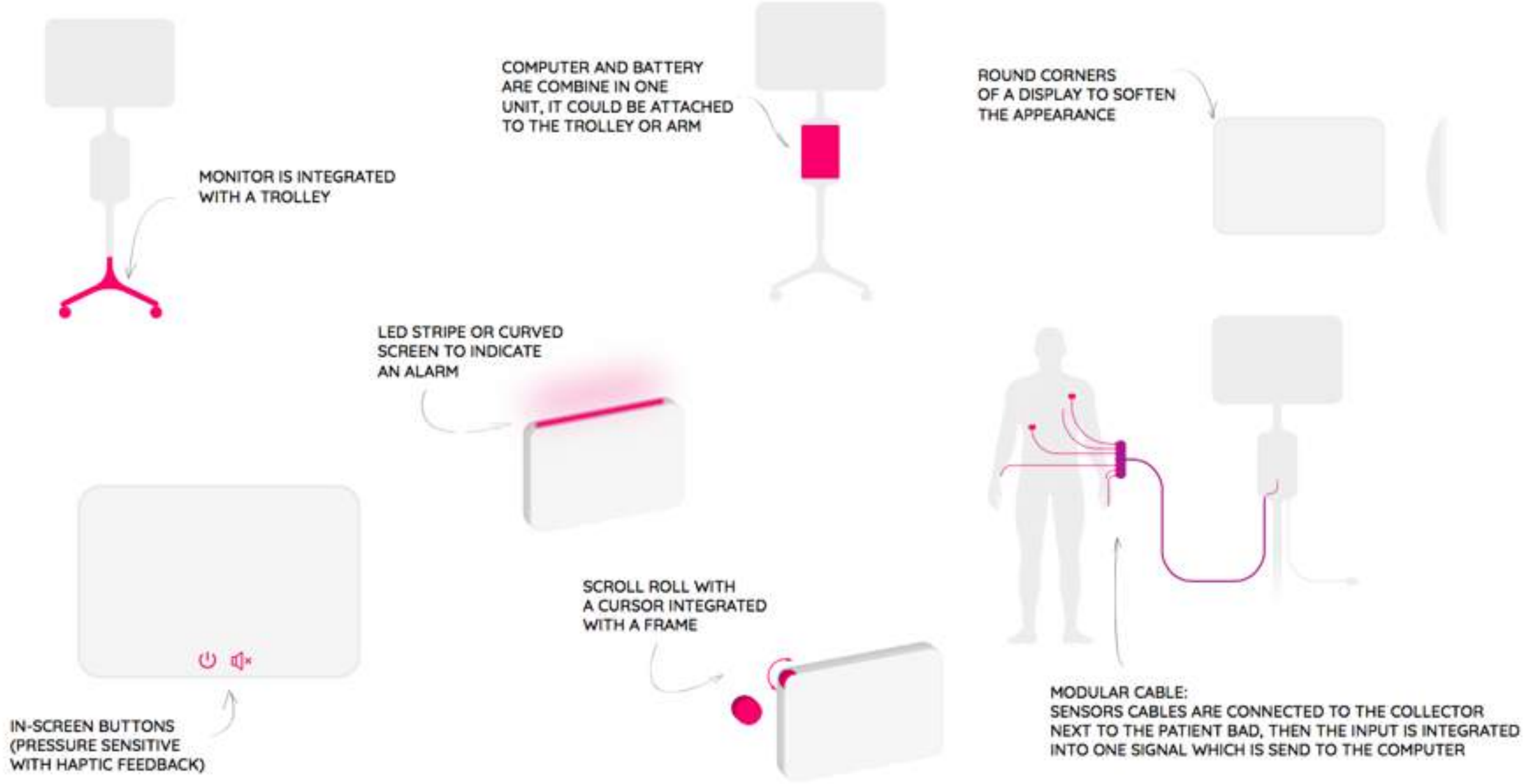
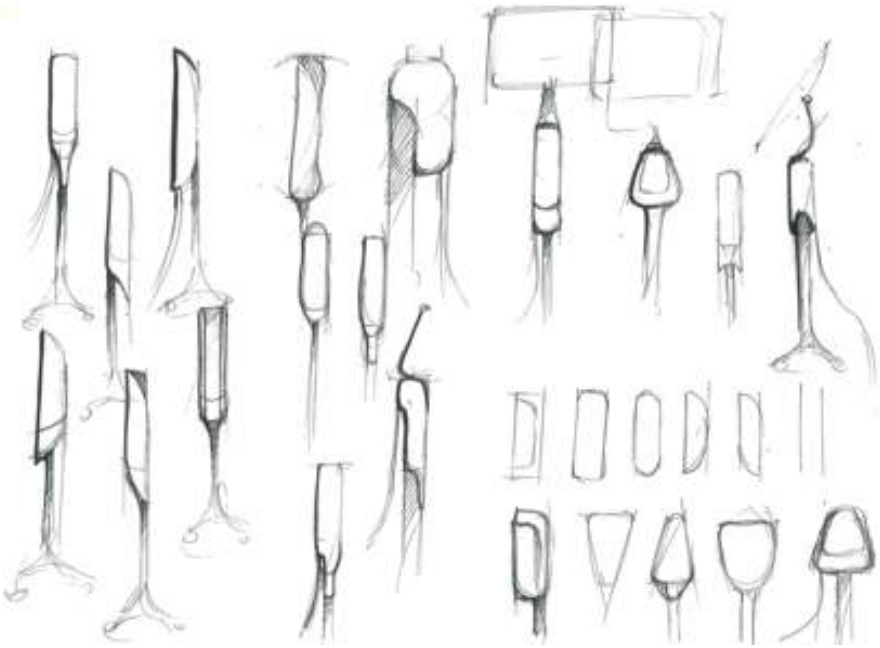
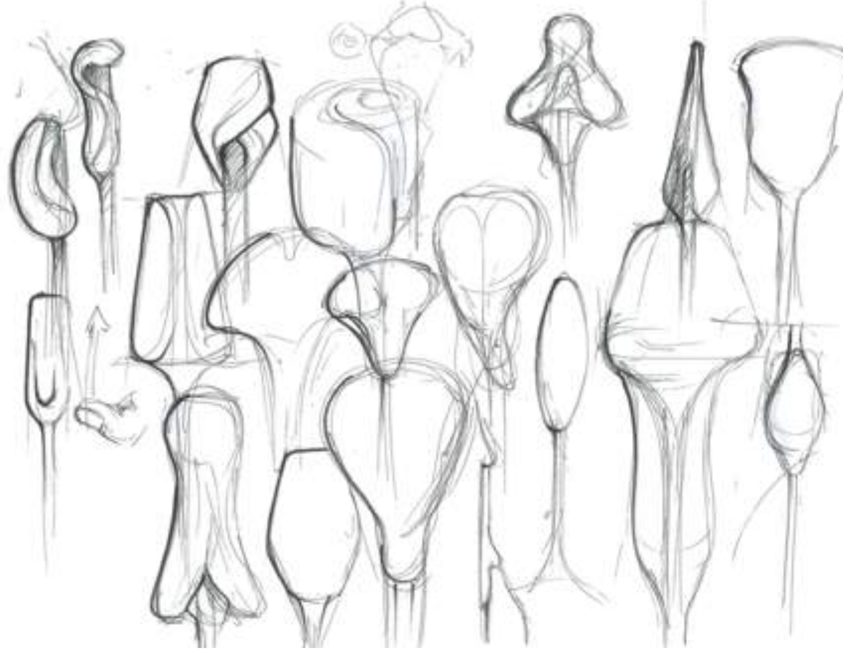
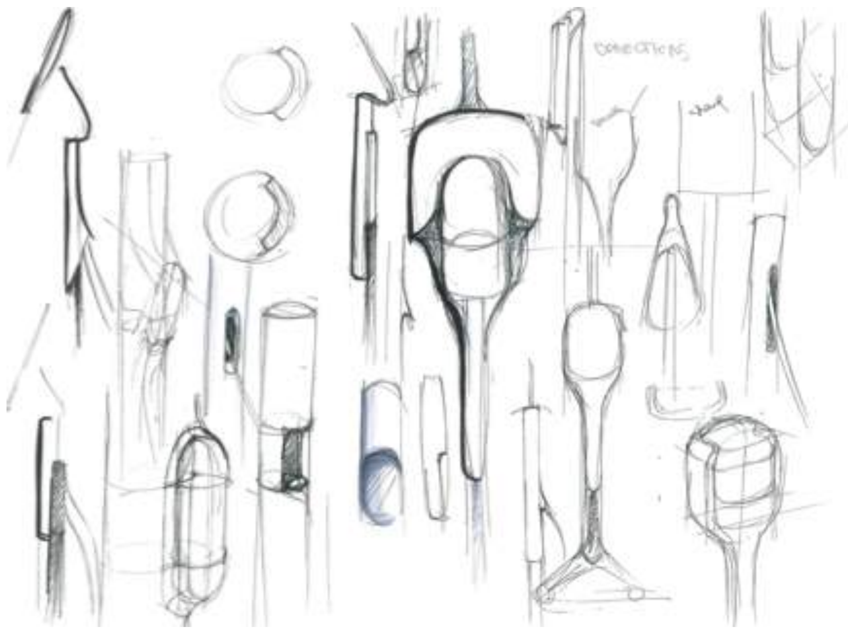
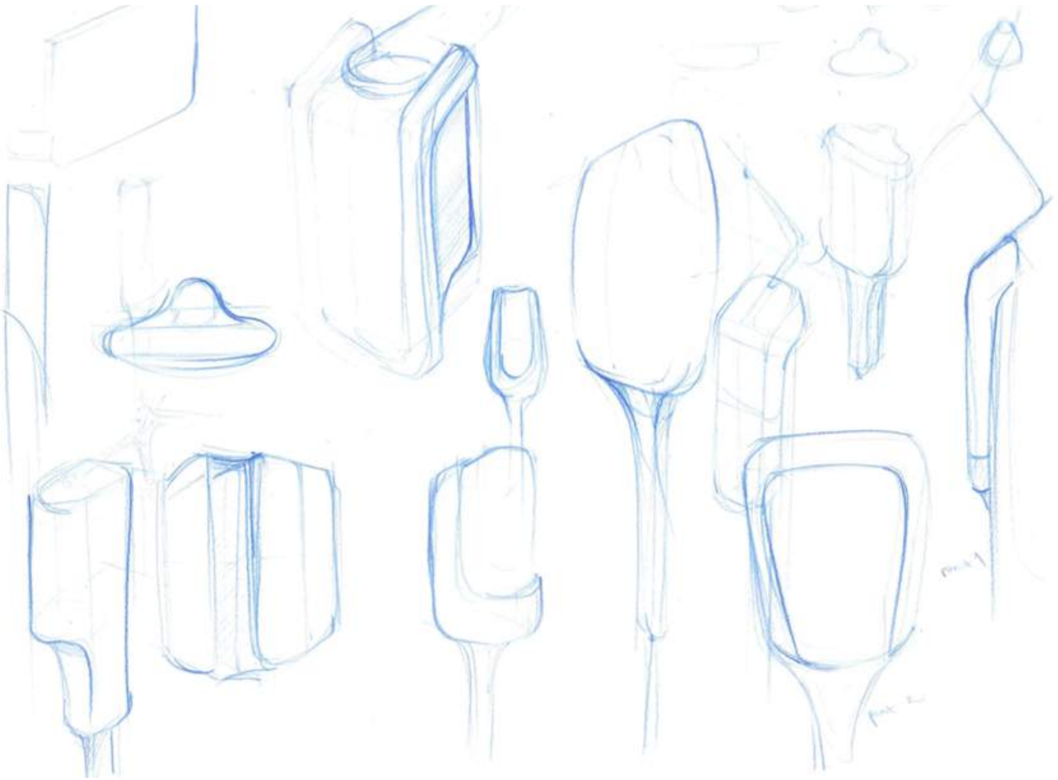


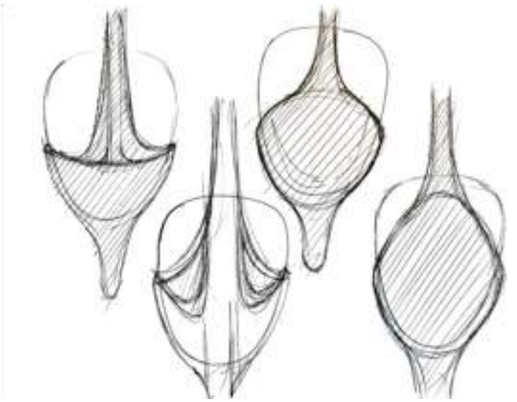
Figure 4.1.6: Design Guidline for the monitor

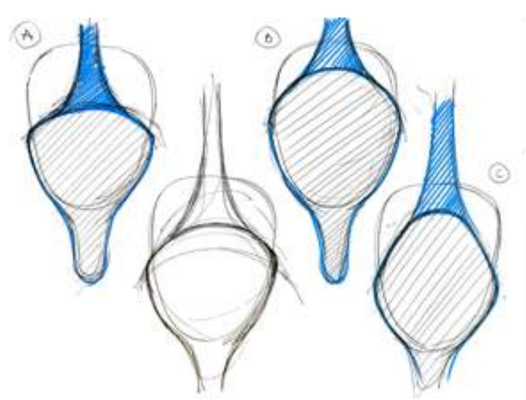


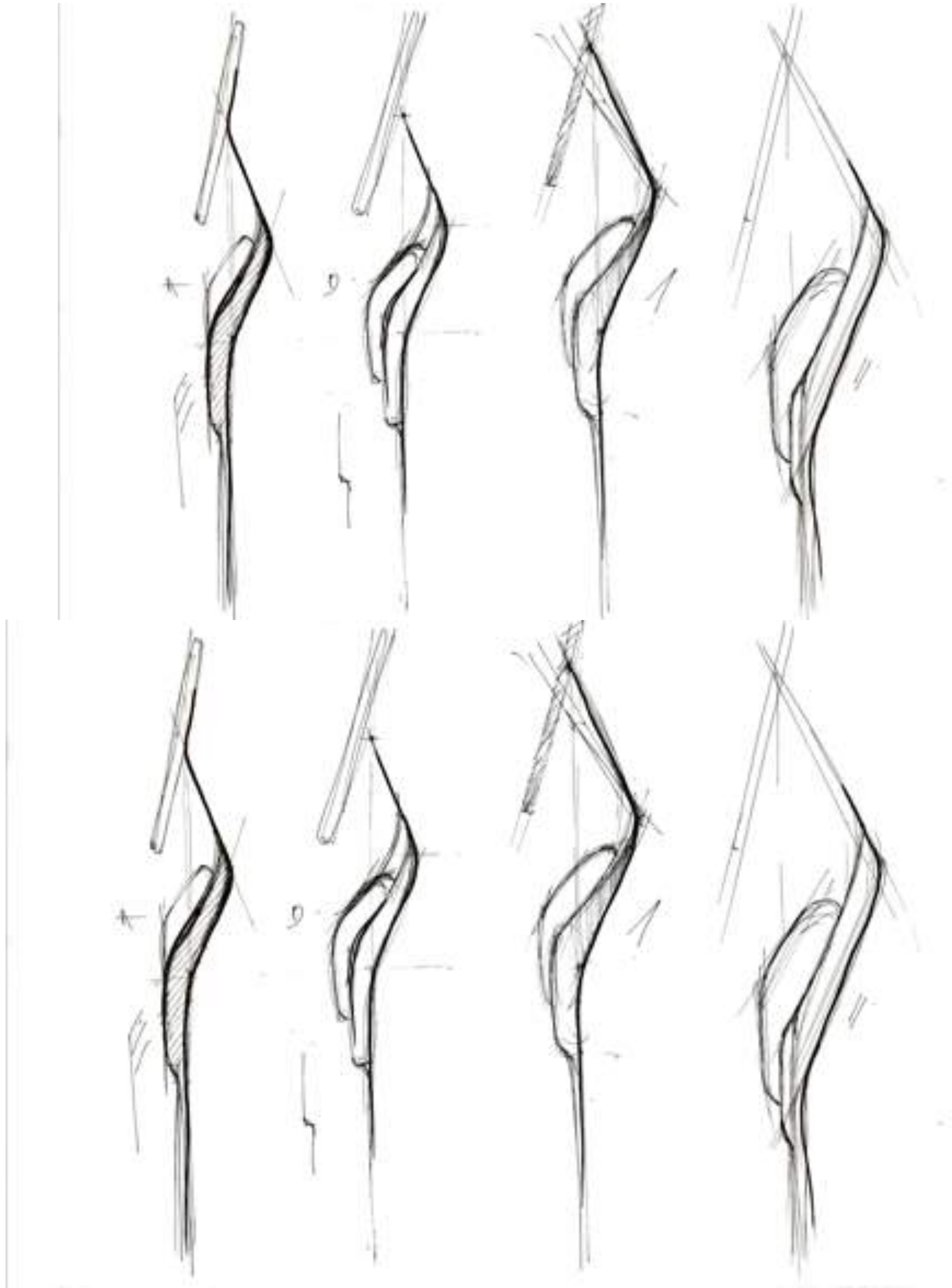












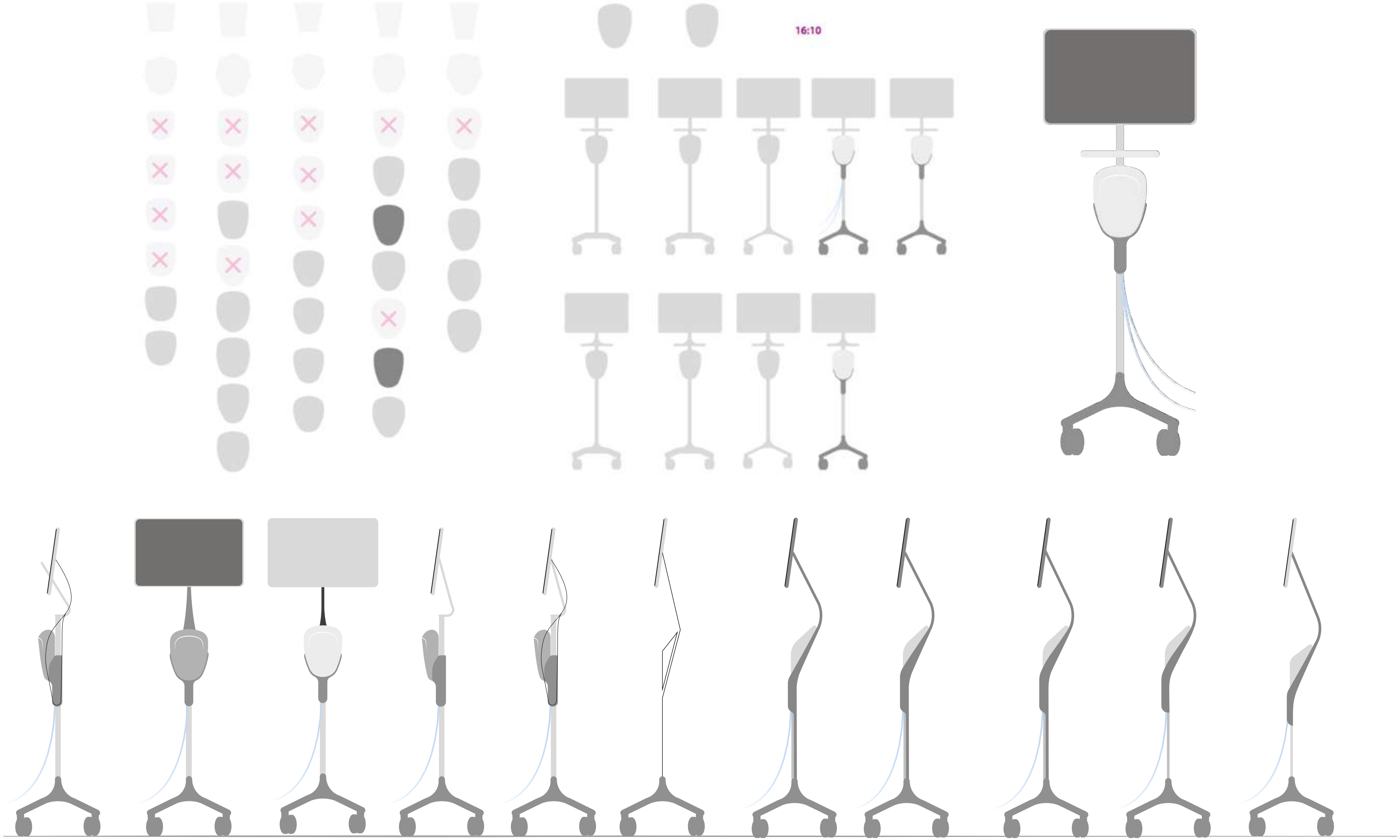


Figure 4.1.7: Shape and proportion selection

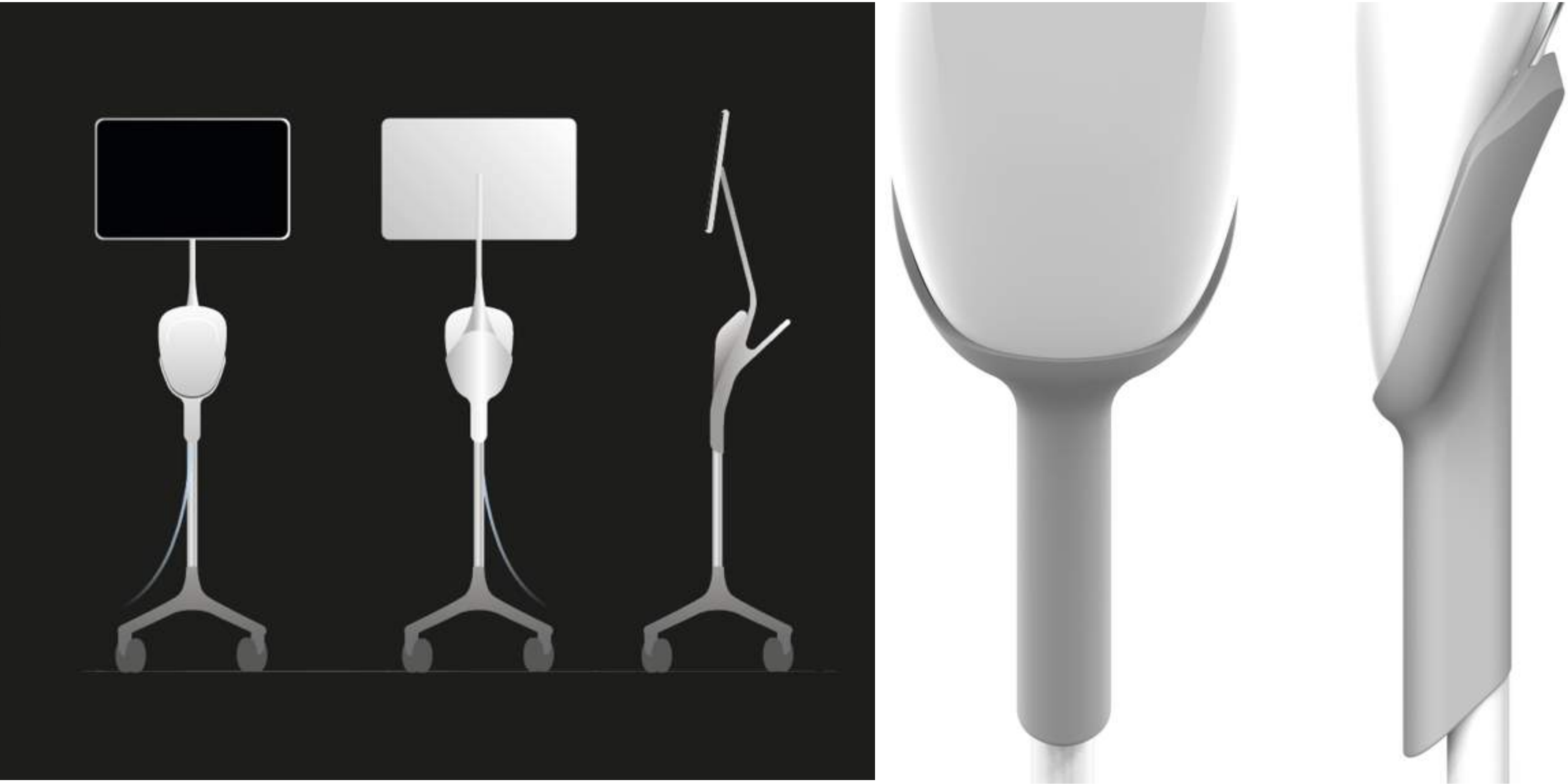
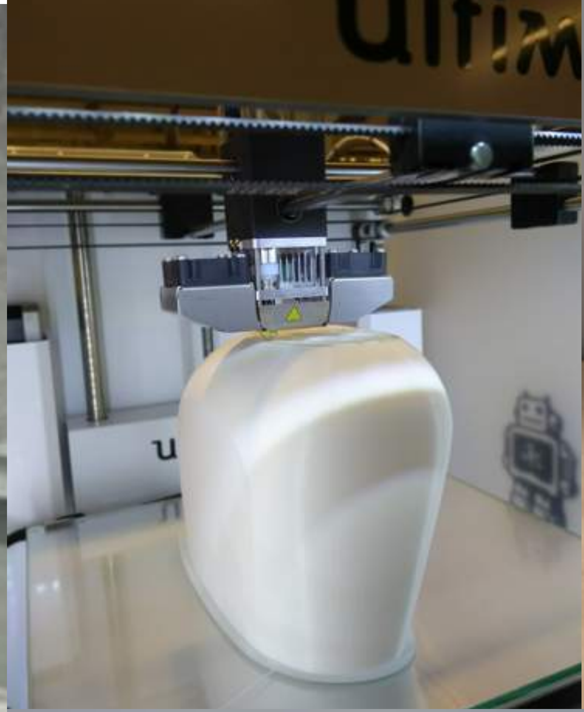


Figure 4.1.8: 3-View and PC details


TESTING

The system includes multiple sensors which communicate with a monitor PC and a display that shows the patient vitals. Therefore, we chose to simulate the scenario in Simulink with real-time data. Various tests were also done to evaluate the final prototype. Its performance was measured by reaction speed and error rate. Last but not least, final user test and test of requirements was conducted to evaluate the outcome.

5.1 MATLAB Simulation of the system

The system includes multiple sensors which communicate with a monitor PC and a display that shows the patient vitals. Therefore, we chose to simulate the scenario in Simulink with real-time data. MATLAB Simulink is equipped with system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink also provides us with the graphical editor, customizable block libraries, and solvers for modelling and simulating dynamic systems.

5.1.1 Simulation setup

The system is spread in different components in a given ICU. Firstly the system comprises a camera mounted on the ceiling near the door of the patient room. Secondly, every clinician carries an identity card with a beacon attached to it. Thirdly, a patient vital monitor with PC attached to stand near the patient.

Detection will be done using cameras and beacons. The cameras mounted on the ceiling near the entrance to every patient box count the people inside. The beacons are used to check whether the person inside is a clinician or a visitor.

Since only the clinicians carry a beacon, a person is identified as a visitor if only the camera is triggered. Clinicians are identified whenever the beacon scanner is triggered

5.1.2 Simulink

The Simulink model is divided into two part, clinician call and display behaviour. In the first model, the monitor is connected with the patient and monitors three patient vitals namely: SpO2, temperature and ECG. The monitor logic monitors these vitals and when any abnormalities in the values are observed, the monitor triggers the respective alarms and sends a notification to nurse central station. Based on the type of emergency, the nurse reaches the patient room with varied speed.

The second part of the system is the display behaviour. Every nurse is given an identity card attached with Bluetooth low energy beacon. This beacon is detected before a nurse enters a patient room. The monitor then changes the display from patient mode to clinician mode as she enters the patient room.

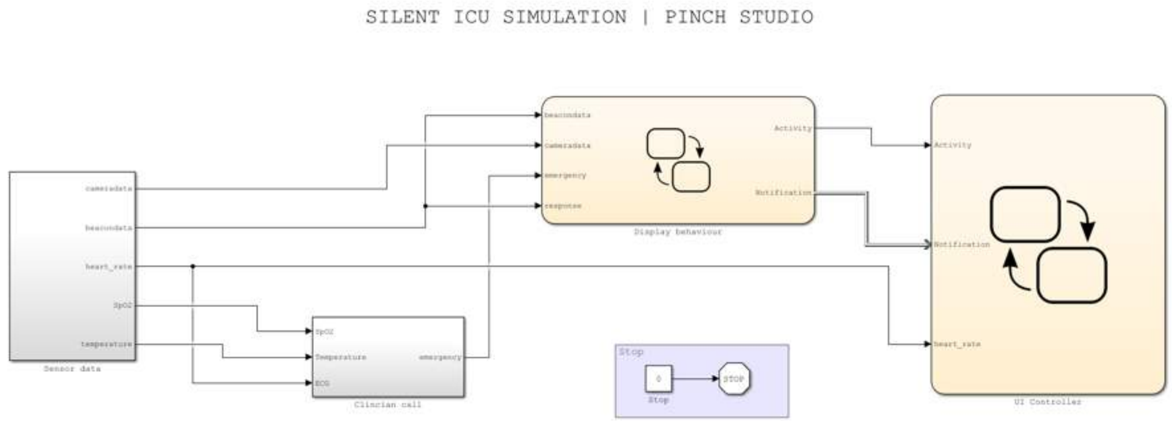
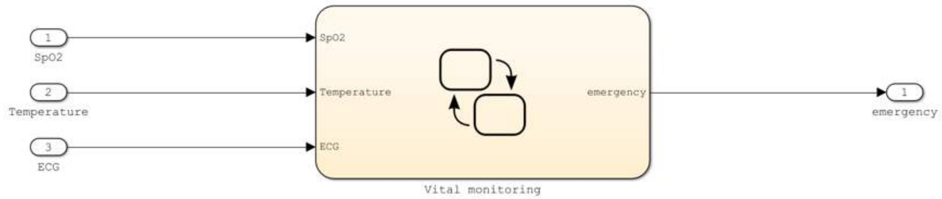


Figure 5.1.1 Silent ICU Simulation

Clinician Call - Setup

As an initial step, the patient vitals are recorded. For this, we have collected the sensor data for 2 hours from a person and loaded it in a signal builder block. The signal builder blocks of three patient vitals send the data to a Stateflow chart. Given the limit for these vitals with an allowable range of values, the Stateflow determines the emergency level and decides when to call the clinician. When a clinician is called and the visitor mode is active, the monitor displays a message saying "Clinicians are on their way" to make the visitor aware of the situation. When such a call is received at the central station, a nurse will come to the patient room.



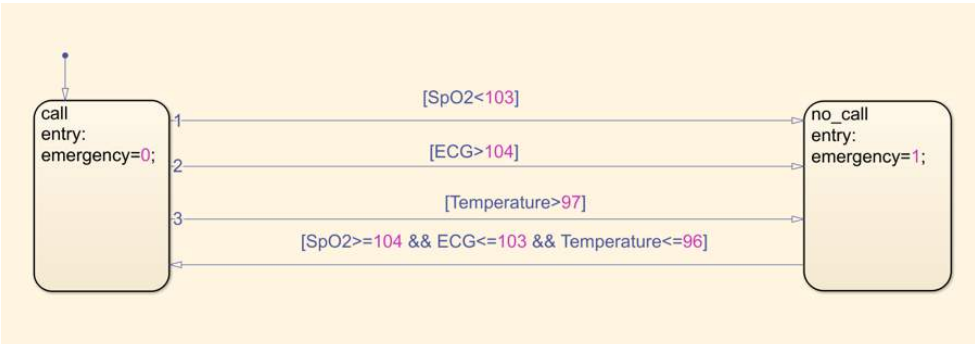


Figure 5.1.2: Clinician call set up in simulink

Display Behaviour - Setup

When the monitor requests a call for the clinician, the clinician enters the patient room. During this event, the camera mounted on the ceiling near the door detects a person entering the patient room. At the same time, the beacon scanner in the PC scans the beacon attached to clinician's identity card and determines the presence of a clinician. Accordingly, the monitor display changes to clinician mode displaying all the patient vitals. As soon as the vitals come back into the normal range, the clinician leaves the patient room. Slowly the monitor switches to the patient mode by muting all the alarms and hiding vital graphs. If the camera mounted near the door observes a person walking into the patient room but the beacon scanner does not receive any signs of a nearby beacon, the Stateflow interprets it as a visitor. Slowly the display changes into visitor mode displaying heartbeat like simple data on the screen.

The camera data has been recorded separately and stored in a signal builder block. This simulates the human walk events of a patient room in a day. When there is clinician call, the UI presents a button to respond to indicate that clinician is attending. When this button is pressed, the beacon scanner detects a clinician that entered the patient room and triggers the display modes.

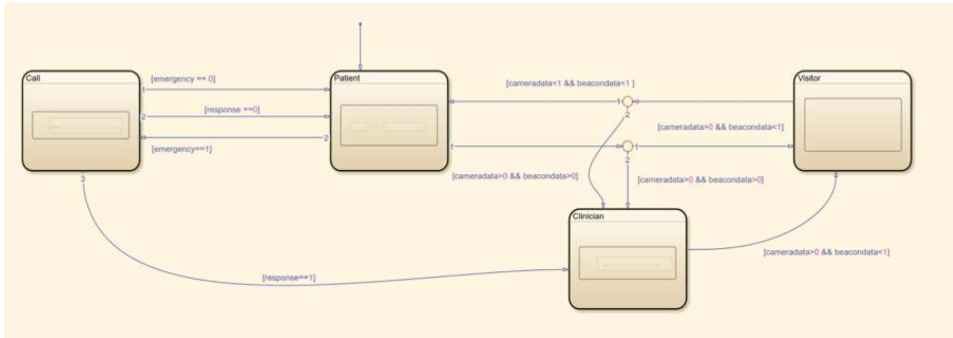


Figure 5.1.3: Display Behaviour set up in simulink

5.1.3 UI controller

The UI controller initiates an app that has been designed in MATLAB app designer. The UI controls what has to be displayed and updated in the app. Whenever the emergency situation has been identified by the Stateflow and the 'Clinician Call' is activated, the UI controller triggers the notification to showing the clinician respond buttons. The clinician can choose to respond to or ignore the situation. When the clinician responds to the call, the UI displays a clinician near the entrance. When the vitals come back into normal range, the clinician disappears. This input will be used to decide the display mode inside the 'Display behaviour' Stateflow chart. Furthermore, the Stateflow chart switches the display mode between visitor, patient and clinician mode according to the modes decided by the Stateflow charts. During the visitor mode, the heartbeat is shown real-time on the screen.

5.1.4 App Simulation

The simulation has been carried out in two different scenarios. One with the current situation with a regular patient monitor. Secondly, the future scenario with ULTIMO monitor. Over the duration of 2 hours, the amount of time the alarms goes off and the amount of time the display is on is observed. In the first scenario of current ICU, the monitor is continuously on with displaying all the patient vitals. The alarms trigger when the vital measurements are abnormal. These alarms sound continuous until the clinician mutes the alarms or until the vitals come back into normal range.

Whereas in the other scenario, where ULTIMO has been deployed, the monitor calls the clinician when there is an abnormal situation and starts the alarms only when the clinician enters the patient room. Thus over the duration of 2 hours, the amount of time the monitor is turned on with all the alarms is comparatively higher in current situation than in Silent ICU. This difference of reduction in exposure to noise has a positive effect on the clinicians and patients.

Figure 5.1.4: App Simulation

5.2 System program Testing

Various tests were done to evaluate the final prototype. Its performance was measured by reaction speed and error rate. Note that system accuracy is greatly dependent on pc performance, the faster the pc the higher the requested speed and frame rate and the closer each shape is to its previous position.

5.2.1 Error Rate

The camera detection error rate is measured by taking pre-recorded footage of people crossing a gate. By analysing this footage and noting down the number of people going up and down by hand, it is possible to compare the system measured values to the actual ones. The figure below shows the number of people going up and down based on two videos (15 and 30 min respectively). Both videos were analysed by hand (actual count) and measured using the Camera_detection.py program.

Table - 1

x	Up	Down
Actual 1	19	18
Measured 1	16	17
Actual 2	16	28
Measured 2	18	25

Figure 5.2.1: Error testing

According to the measurements, the system is 89% accurate in detecting people crossing the gate. This is far under the percentage applicable in a hospital environment, however, this project is still in an early phase and many improvements can be made to this current system. These improvements need to be made by someone who is proficient in computer science since it requires their expertise to improve the coding.

The beacon error rate is measured by the fluctuations of RSSI value when stationary. Since the RSSI value is used to determine whether a person is in the room or not it is essential to calibrate it correctly. In this test setup, all beacons are placed next to each other at the same fixed distance from the scanner. Figure 5.2.2 shows five beacons with the past 12 measured RSSI values.

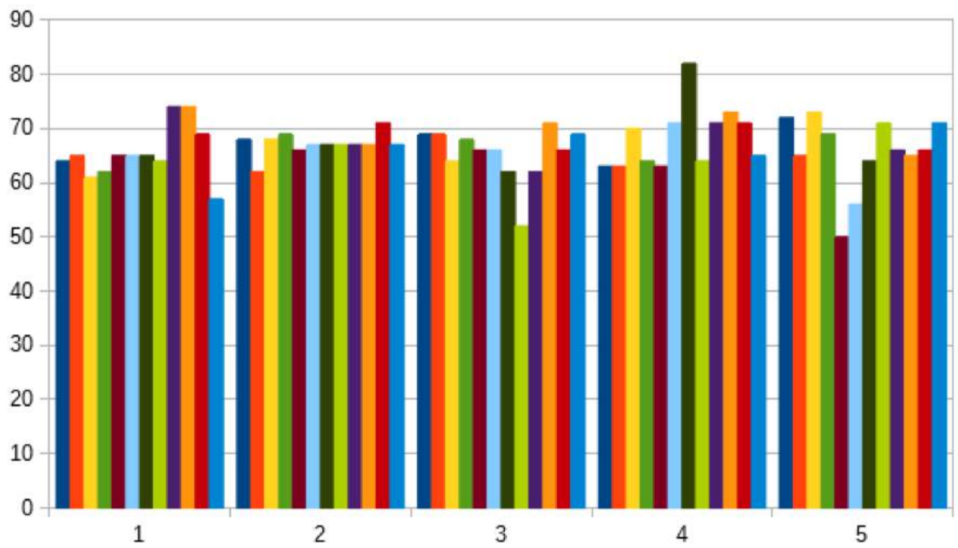


Figure 5.2.2: Beacon RSSI values

As shown above, the beacon RSSI value fluctuates quite a bit during a stationary measurement and the average of this also differs slightly. Figure 16 shows all measured values over all beacons indicating the outlier measurements.

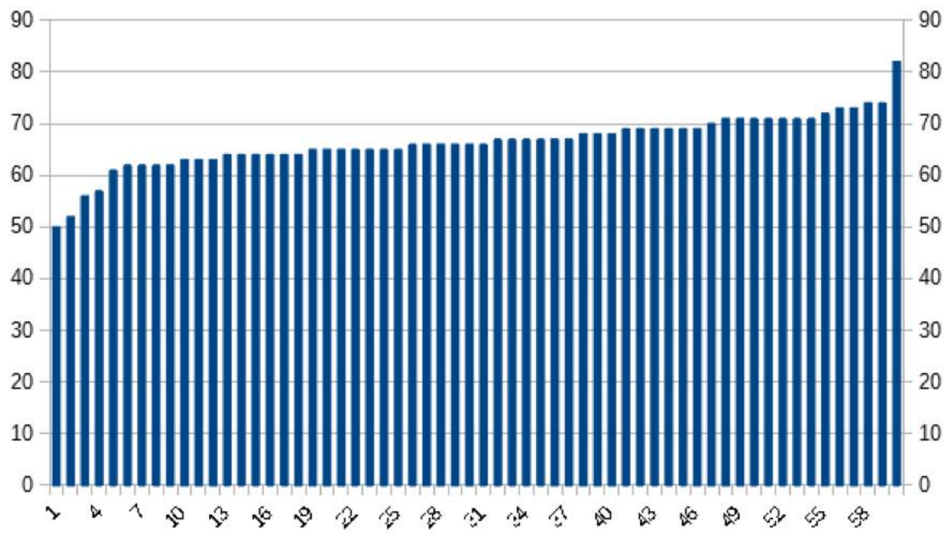


Figure 5.2.3: All beacon RSSI values

Beacons RSSI values can fluctuate from around 50 to 80 at a stationary similar distance. This fluctuation is partly accounted for using an average RSSI value, which results in a fairly consistent value.

5.2.2 System speed

The speed at which beacons can be detected is dependent on their advertisement frequency. Currently the beacons are set to do so every 100 milliseconds. However since the system has to work with an average value, in this case 12, measurements it will take 12 measurements for the system to average down when someone is entering. It will also take another 1.2 seconds get an consistent reading. This means that It might take up to 2.5 seconds before a clinician is detected after entering the patient box.

The speed at which the system detects is equal to the framerate. The motionEye camera can read images up to 30 frames a seconds which is more than enough in terms of speed. Running the detection software simultaneous with other processes will decrease the frame rate, but not in such an extent as to significantly affect detection speed. Slowing down frame rate does affect error rates as explained previously.

5.3 Final test

The separate parts of the system has been checked. The accuracy of the system had been improved and a test on the visitor mode provided insights. In the end the whole system was put to the test. A short user test (10 participants) showed the insights into final product. First, a participant was briefed on the scenario, visiting family or a friend in the intensive care. Then the participant was led into the Care lab at the Industrial Design Engineering faculty of the Technical University of Delft. Entering this room, the participants saw a patient room, including a patient bed and a traditional patient monitor shown on a tv screen, including sounds. After they entered the room and saw the monitor, the participants were asked to start filling in a questionnaire on a tablet. After they filled the questionnaire, the participants were asked to leave the room. When the participants were asked to reenter the room, the traditional monitor screen was replaced by the new one, showing the patient mode (animated). When the participant, acting as the visitor, entered the patient room, the screen switched to visitor mode. The screen showed then the new visitor screen that was developed using the results of the product experience research.

During the time the participant is in the room, the visitor mode switched from a stable status to another status. Hereafter, the participants were asked to once again fill in the questionnaire. The results were analyzed using a similar method to what was used during the product experience research. Below are the result of the comparison between the two monitors.

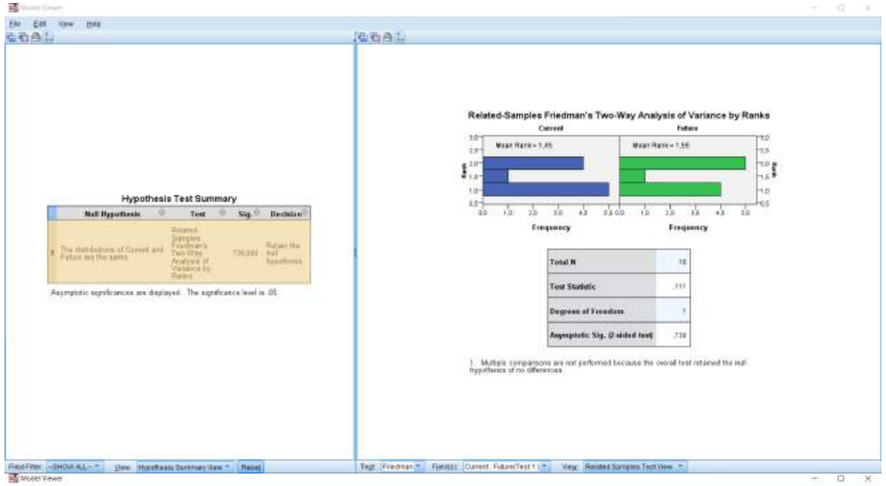
Between the 10 participants, there were two groups, one starting with the current display the other starting with the new display.

Question one, how informed do you feel?

As can be seen, the current and new screen do not have a significant difference between their mean ranks based on the perceived information given. This is a positive outcome. It means that the participants do not feel like they are missing information.

Question two, how well do you feel like you understand the patient’s status?

As can be seen by the Friedman's two-way analysis, there is a significant difference between the mean ranks between the current and new display based on the perceived understandability. Which means that the participants could better understand the new monitor. This means that we reached our goal to present easier to understand information.



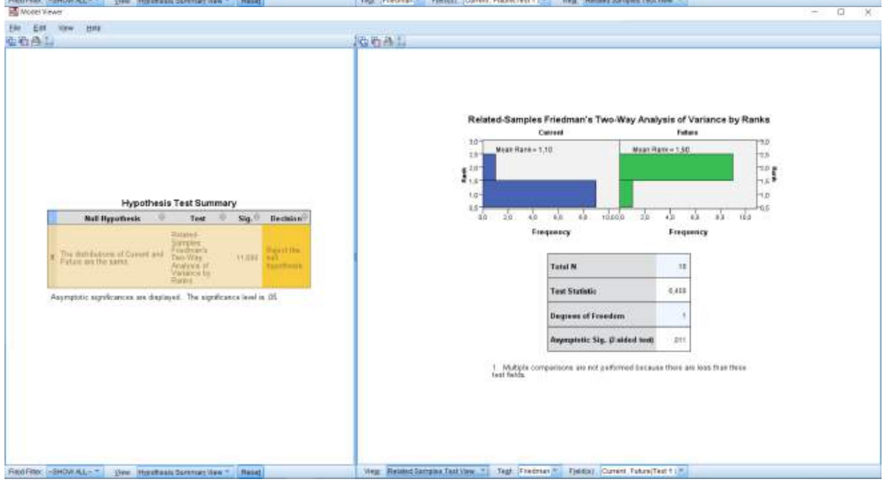


Figure 5.3.1 : Question one, how informed do you feel
Figure 5.3.2 : Question one, how do you feel like you understand the patient's status

Question three, how reliable do you perceive the monitor?

As can be seen, there is no significant difference between the mean ranks on the perceived reliableness of the monitors. Meaning the new monitor is perceived as reliable as the current one. This is a fast improvement with the previous research. This means that it is possible to change the monitor display from the current one even though this changes the traditional patient room.

Question four, how thankful do you feel for the monitor?

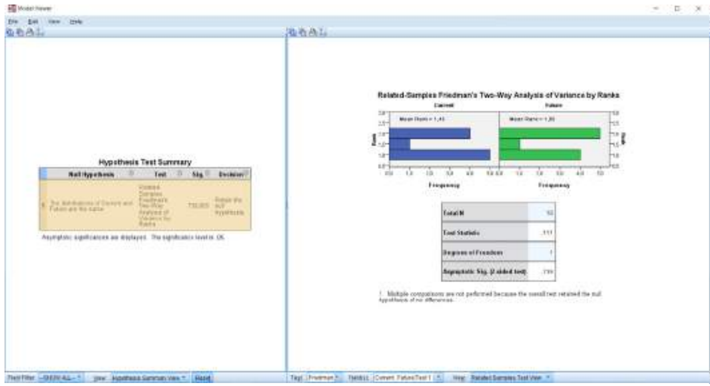
There is no significant difference between the two monitors mean ranks in perceived thankfulness. Ideally this would be higher for the new monitor. This could be one of the parts to improve in further iterations of the visitor mode. The new monitor is in the right direction since its mean rank is higher than the current monitor's.

Question five, how anxious makes the monitor?

The mean rank of the current monitor is significantly higher than the new monitor based on perceived anxiety. This is definitely an improvement. The aim was to lower the perceived anxiety, which is done by introducing the new monitor.

Question six, how peaceful does the monitor look to you?

The graph clearly shows that the mean rank of the new monitor is significantly higher than the current one. This was the whole goal of the new monitor, inform and calm the visitor. The goal is reached.



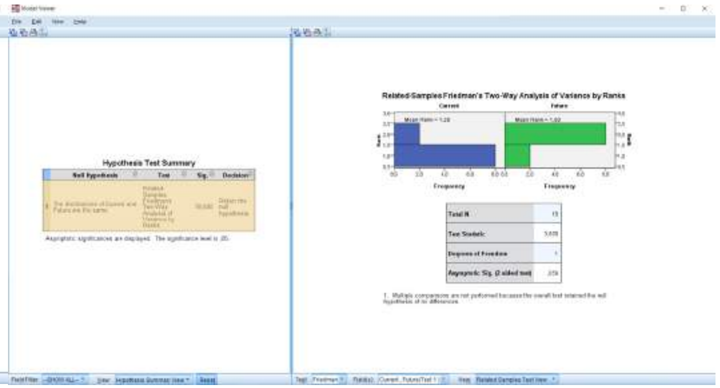
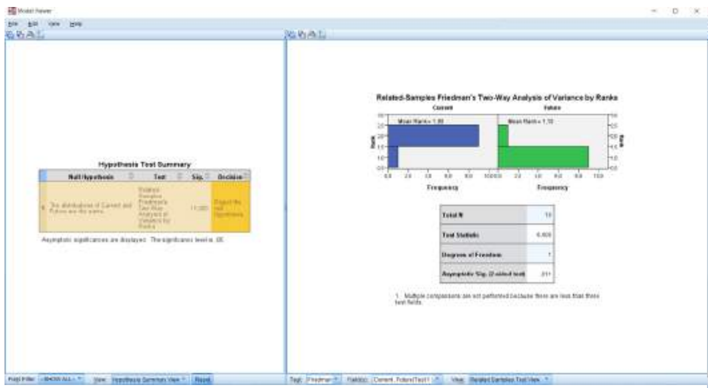


Figure 5.3.3 : Question three, how reliable do you perceive the monitor?

Figure 5.3.4 : Question four, how thankful do you feel for the monitor?



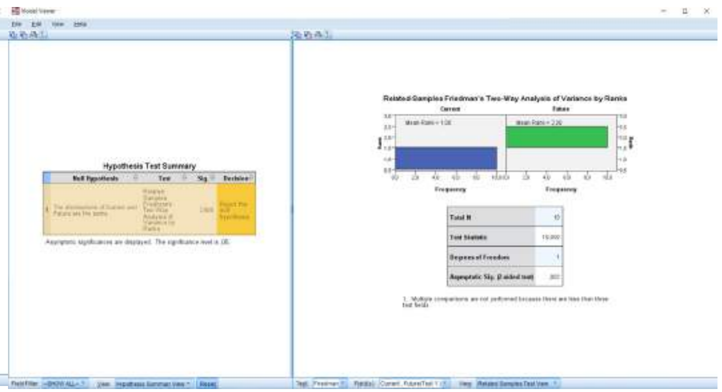


Figure 5.3.5 : Question five, how anxious makes the monitor?

Figure 5.3.6 : Question six, how peaceful does the monitor look to you?

Question seven, how peaceful does the environment look to you?

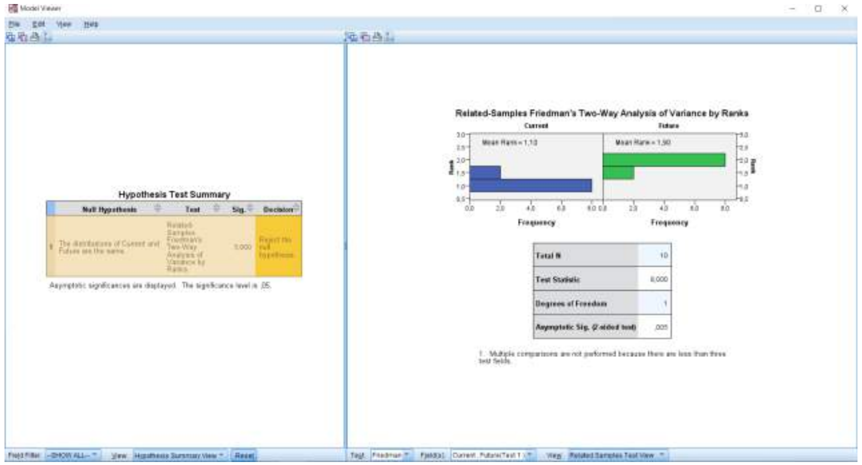


Figure 5.3.7 : Question seven, how peaceful does the environment look to you?

Not only did the new monitor improve the perceived peacefulness of the monitor, it also significantly improved the environment.

Question eight, would you mind staying in this room for over an hour?

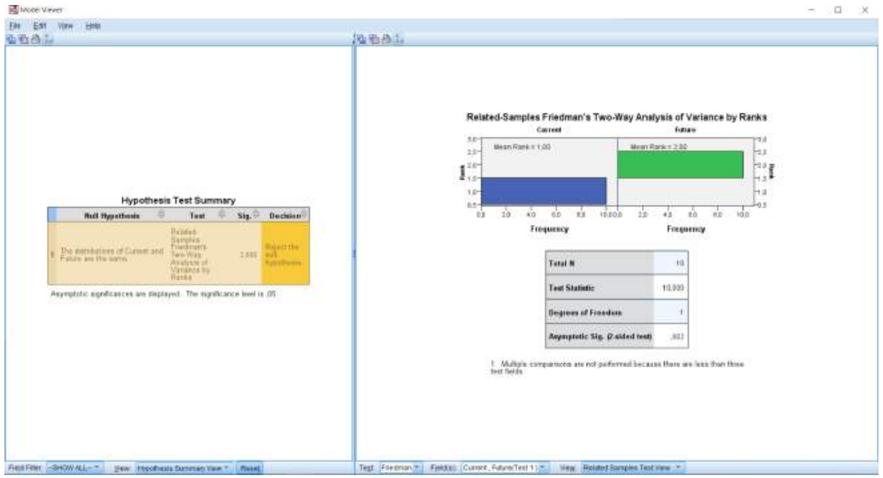


Figure 5.3.8 : Question eight, would you mind staying in this room for over an hour?

Finally the mean rank of the new monitor is significantly higher than the current monitor based on the how easy the participants would be able to stay in the patient room.

In the end the user test showed that the perceived stress, confusion and anxiety by the visitors is significantly lowered by the new monitor. The new monitor improves the time the visitor spends visiting their relative or friend in the intensive care. The participants mentioned that they found the new monitor was a fast improvement on the current monitor.

5.4 Test on Program of Requirements

Comparing the final design and prototype to the List of Requirements (Page 11) gives a positive result. The UltiMo meets most of the requirements, even in this early stage. There are two requirements the current system does not meet. However, the further developed UltiMo system will likely meet these requirements.

The requirement of 99.9% accuracy and the FDA approved. Although the current system does not reach the accuracy requirement right now, with further development this can be done. To reach the FDA regulations, the regulations have to be changed. The initial idea of silencing alarms is not possible as of now. The UltiMo is developed to inspire the medical field and encourage them to innovate and make changes. So that in the future the FDA requirements change and a silent ICU is possible.

Furthermore, the current beacons are placed on the identity cards clinicians carry in the Erasmus. Even though most hospitals have clinicians caring identity cards to place the beacon on, this is not necessary. The beacons could be worn stand alone, on something else or be integrated in the pagers.

CONCLUSION

Conclusion

In the end, the prototype works as intended. The interface consists of the people counting and beacon detection, which enables the system to change its display according to the sensed data. Although the system is working, refinement is still needed. Achieving a 100% accurate system is barely possible. It was not only impossible given the time allocated to the project, but also required expertise that was not present within Pinch studio.

Furthermore, the system is at (even slightly past) the point where it would be passed over to a seasoned programmer who has experience with computer vision, BLE scanning, data plotting and the creation of Graphic user interfaces. In addition to the improved accuracy, the future system should include improvements in usability, system reliability, scalability and speed.

To ensure proper working, additional testing is needed. Moreover, the addition of sounds and screen transitions could improve the user experience.

The current system makes use of single board computers and freeware. which is not ideal. To optimize the system the single board computer should be replaced by a custom, dedicated and optimized PCB. When the future system does use freeware, software security should be added.

In terms of visuals, both the screen and the monitor itself is worked out in great detail. Even though it was not a prime objective to design both the screens and embodiment of the monitor, a lot of time was invested in it. This resulted in a convincing and well thought through design. The monitor has a sleek, elegant and friendly look, clearly separating itself from conventional hospital equipment while not standing out too much.

As with the system, the design of the screens needs further testing. Although the test has been done surrounding the visitor mode, a new result with a bigger sample group could result in definite facts. Furthermore, testing on the other users like clinicians and patients would result in facts on what to show to the different users.

All in all this project proved that the vision of a silent ICU is not just wishful thinking, but actually feasible with plenty of stepping stones to complete integration. The foundation of a smart monitor has been made. The project definitely needs further development to get the remaining 10% accuracy and more studies are required. This will take at least another six months and additional expertise. The next chapter will discuss what changes can be made to eventually finalise the project.


1mV
HR
80
Pleth
SpO2
99
ABP
120/80
(93)
PAP
26/10
(16)
etCO2
CO2
NBP Manual
NBP No Cuff
Touch when cuff attached
Manual
TOF%
TOF

FUTURE

Further development of this project should be done by splitting it in multiple sections. Alternatively a multidisciplinary team of designers, engineers and programmers could work together. This chapter covers the different parts of the project that require further development and pose possible solutions to problems that arose during development. The project can be split into 3 categories; software, embodiment design, product experience.

7.1 Software

As noted in the evaluation, the system is still in early development. Therefore it still needs improvement to be more accurate and user friendly. This chapter covers the possible improvements to the current system that could make it more reliable.

7.1.1 Improve accuracy

The accuracy of the system can be improved in many ways. Both the camera and the beacon software can be upgraded to work better in a wide range of situations.

First, the camera frame/gate coverage needs to be increased in order to make sure everyone is detected including those who are entering close to the side of the gate. This can be done in multiple ways: decrease entrance size(not possible in most situations), increase camera mounting height(is limited to ceiling height), use wide-angle camera(creates distortion and needs to be calibrated because of that) and using two or more cameras(need to be stitched together and synced). Preference goes out to using multiple cameras since this would cause minimal distortion.

Secondly, the shape detection and path tracing can be improved by increasing the frame rate and running the camera detection on a different thread separate from the main program. The program could also post updates to a server only when a change is detected. Aside from this many factors in the program influence the detection and can be optimised further like; subtractor history, shape filter size, max age and new shape threshold. It is also possible to set multiple gatelines to improve readability.

The beacon sensing can be upgraded by using multiple beacon scanners per room to get a more accurate positioning of the detected beacons and possibly increase detection speed. Placing a beacon in every corner of the room would allow for accurate positioning and would make the system more redundant.

Lastly, the beacons themselves could be calibrated to account for the difference in RSSI values between beacons with the same distance. Thereby eliminating the problems covered in the system evaluation.

7.1.2 Build initialisation

The initialization process of the beacons can be improved by making the setup as straightforward as possible. An initial screen should prompt the user with all required information about IP addresses etc. The setting of the limits of the camera detection should be done using simple mouse clicks. Currently, the limits have to be changed in the code. This requires guesswork on where to position the lines to correctly line up with the gate. The program needs to store data about which clinician carries which tag and has to be organised for a better readability.

7.1.3 Added functionality

Aside from optimisation, the system itself can be upgraded with more functionality. The beacons can be integrated into existing pagers. It could then send a signal when nurses accepted a call and are on their way to a patient. This would result in an additional screen in the GUI which states that a clinician is on their way ensuring a visitor the patient is taken care of. Beacons can also be linked to each clinician personally instead of as a ‘tag’ thereby allowing for personalised clinician screens based on their screen and layout preferences.

7.2 Embodiment design

In the later stages, the embodiment needs to be developed with actual materials. This includes medical grade plastics and metals that satisfy the factor of safety.

Materials & production process

The infinity display monitor uses 24 inch LED display with touch screen module. The monitor uses actual pressure sensitive buttons under the screen for manual override. So, precise selection of touch screens is necessary. It is advised to use Projective Capacitive touch (PCAP) sensors for the touchscreen module of the display. Secondly a sensitive pressure sensor needs to be placed under the screen. Coming back to the outer shell, the bezel is made up of white anodised aluminium. The scroll wheel can be made either in ABS plastic or anodised aluminium. To synchronise with the design, it is advisable to manufacture it in aluminum. The back and front of the monitor, are covered with Corning Gorilla glass for high optical clarity and scratch resistance.

The neck part onto which the PC is mounted is made up of aluminum with brushed finish. This part being quite complex at the bottom, it is advisable to manufacture through casting and milling. Since the wiring needs to be routed through the neck part, it is required to manufacture the neck in two separate parts that are split vertically. The basket was designed to be produced in medical grade plastics like Acetal Copolymer. It is a semi-crystalline thermoplastic with high strength, stiffness and toughness.

The basket has an internal routing detail for the network cable and power cable. Since basket is a hollow part of the body, it is necessary to define the parting line according the allowable drafting angle of injection molding. The internal routing details needs to be designed in such a way the part could be manufactured through high speed injection molding. Overall, the basket need to be produced in four different parts in injection molding ad assembled together.

The telescopic tube which holds the basket is a simple extrusion of aluminum or nylon pipe. Generally nylon telescopic tubes work best from a diameter of 35mm. In the current situation the diameters of telescopic tubes are 30 and 34 mm. So, a conscious decision needs to be take on the material of telescopic tubing based on structural simulations.

The wheelbase is best made up of aluminum. To maintain a stable support for the monitor and basket, it is advisable to make the wheelbase out of aluminium rather than polycarbonates. Finally the casters can be a regular off-the shelf caster or a customised caster with made up of regular materials.

The camera has design has been made it simple to injection mold in ABS or Acetal. The camera has two simple enclosures which that obey the drafting angle from both the sides. This makes it easier to manufacture with least effort. On the other hand, the beacons are simple pcb’s overmolded with silicone. These beacons are made for one time usage. Ones the battery is empty, the beacons are replaced with new ones. So overmolding would be the simple and quickest possibility to manufacture them. For this it is necessary to use either Class V or or Class VI silicones which are medical graded non-implantable silicones.

Installation guide

With the future in mind, the Ultimo product also requires installation into various hospitals. This part proposes a short future installation guide imagined for the final product. It covers both installation and initialisation of the hardware and software.

Step 1, monitor:

Unpack the monitor and position the monitor stand in the preferred location. Place the PC on the monitor stand. Connect the power cable, sensor panel and Ethernet cable to the monitor. Start the pc and setup all connections to the network. Connect all sensors to the sensor panel and make sure everything is working properly.

Step 2, camera:

Mount the camera backplate to the ceiling(or wall) inside the patient box near its entrance. Ensure that the backplate is parallel to the entrance and no further than 30 cm from the gate. If ceiling mounted, drill a hole for the LAN cable. The camera gets its power through the LAN cable and does not require any additional power source. Wire the LAN cable through the backplate and plug it into the camera. Slide the camera onto the backplate. Connect to the camera via the monitor inside the patient box and set the entrance bounds in settings - camera - initialise camera. Enter camera positioning height for correct detection(from floor to backplate) and fill all required fields(room number, etc.). Save and quit. The camera is now connected and initialised to the patient room. Ensure proper working by leaving and re-entering the patient box. Go to view - history - camera and check the camera detection.

Step 3, beacons:

Place a beacon on the Ultimo PC. Navigate to settings - beacons - initialise user. Select existing user profile or fill in a new clinician profile. Ensure the beacon id corresponds to the beacon placed on the pc. Save and quit. The beacon is now connected to this room. More users can be added or switched between in settings - beacons - Users. The battery can be checked in settings - beacons - info. The monitor will notify users when a new beacon is required.

7.3 Product experience

7.3.1 Visitor Display

From the previous research (chapter 3.7), several suggestions were made for further implementation of visitor display as shown in figure 7.3.1.

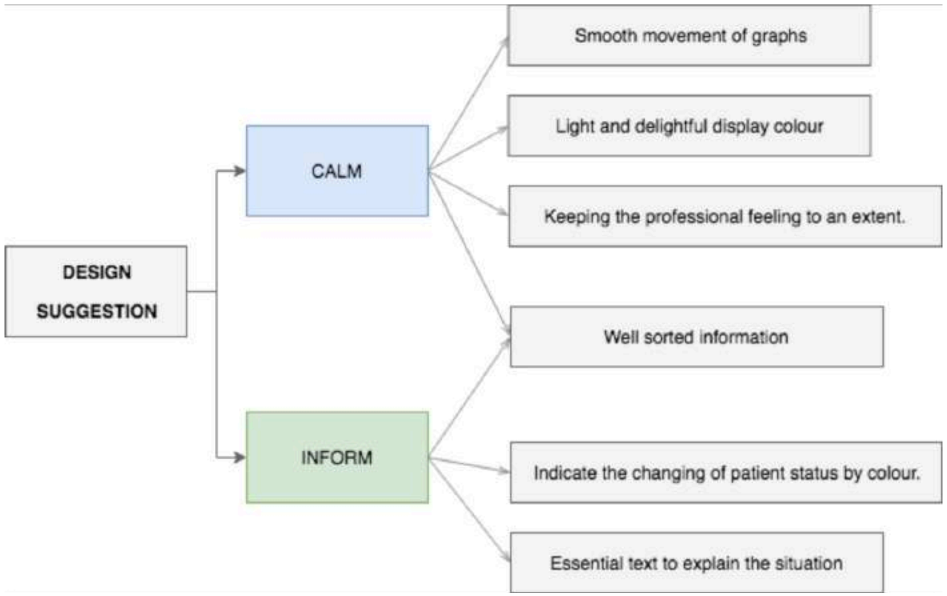


Figure 7.3.1 : Design Suggestions

There seems to be a fine line between too little information and too much. This line not only shifts from person to person but also from situation to situation. Due to the complex nature of the problem an additional research is required. To obtain more reliable results a larger number of participants, with and without the experience as an ICU visitor and with diverse education level, is recommended. Moreover, some participants changed their mind during the research, about how informed they felt with certain information. Therefore we suggest extending the duration of the study. It will enable the participants to accustom to the new displays and analyse if, with time, their answers change. Non-negligible is also the context of the study. The used Care Lab partly mimics the patient box but doesn't depict the ICU hostile environment. This could affect the results. In order to get a more accurate result, further research should be conducted in the ICU environment.

7.3.2 Clinician Display

he display for clinician mode can be optimized in the future with further research. During the research on visitor mode, two versions of the current display were shown to participants for comparison. Aside from the content that is difficult to understand, people also found the layout very cluttered. The contrast of colours and the arrangement of information made the display rather overwhelming. These views on the look of the display may be similar to the clinician's and have no relation to professionalism. Future research can be conducted, preferably on clinicians, to rearrange the parameters and make the display more user-friendly. Considering the workload of clinician and the time they spend looking at the monitor per day, the study shouldn't be testing the impression. Instead, it should monitor the experience and influences during a longer period and use of the monitor. The research could also incorporate the interaction between participant and monitor in order to test the usability.

REFLECTION

During our project we faced various challenges that influenced the outcomes of the prototype. The fact that we were not able to use the dräger monitor in our prototype, limited the outcome in a ready to implement prototype. As did the challenge of the coding. During the prototyping of the system, we concluded that the coding would not be as simple as we thought. It became clear that to make a properly working system that is reliable, coding expertise was necessary. With the help of a coder friends and a freelancer we were able to develop a prototype that was still fairly accurate. Not nearly accurate enough to place in a hospital, but accurate enough for a working prototype. Our coder friends helped us get in the right direction and were so kind to answer our question when we were stuck. The freelance enabled us to put the different coding parts together in one system that was able to work and communicate together.

During our project we spend a lot of time diverging, researching various detection methods. During the first quarter, a lot of time was spend researching different areas. Due to the fact that the starting point of this project was more of a vision than a solid idea that had to be further developed into an embodiment design, this research was necessary. The outcomes of the first quarter resulted in a good foundation on which the system could be designed. This required researched did result in a shorter time that was spent on the actual development of the system.

Furthermore, during our project we developed more than the initial system that was the goal. Alongside the development of the system a new design vision for the patient monitor was developed. Not only represents the new monitor the innovation and calmness the UltiMo aims to bring, it is also designed in they same styles as the beacons and camera.

Lastly, Pinch studio aimed to design a the new visitor mode the UltiMo introduces. This proved to be a difficult subject that requires a project of its own. Nevertheless did we develop a starting point for this project and was a design for the visitor mode developed according to the results from the user test.

In the end there was a lot developed in during this project. Various parts have been explored and multiple parts of the whole system have been designed and developed. Nevertheless, the system still needs more development and the project is not ready for production and implementation. Even though further development of the working system prototype (the software and hardware part) requires expert knowledge to fully develop, we might have been at a further stage if we had converged our attention to this part.

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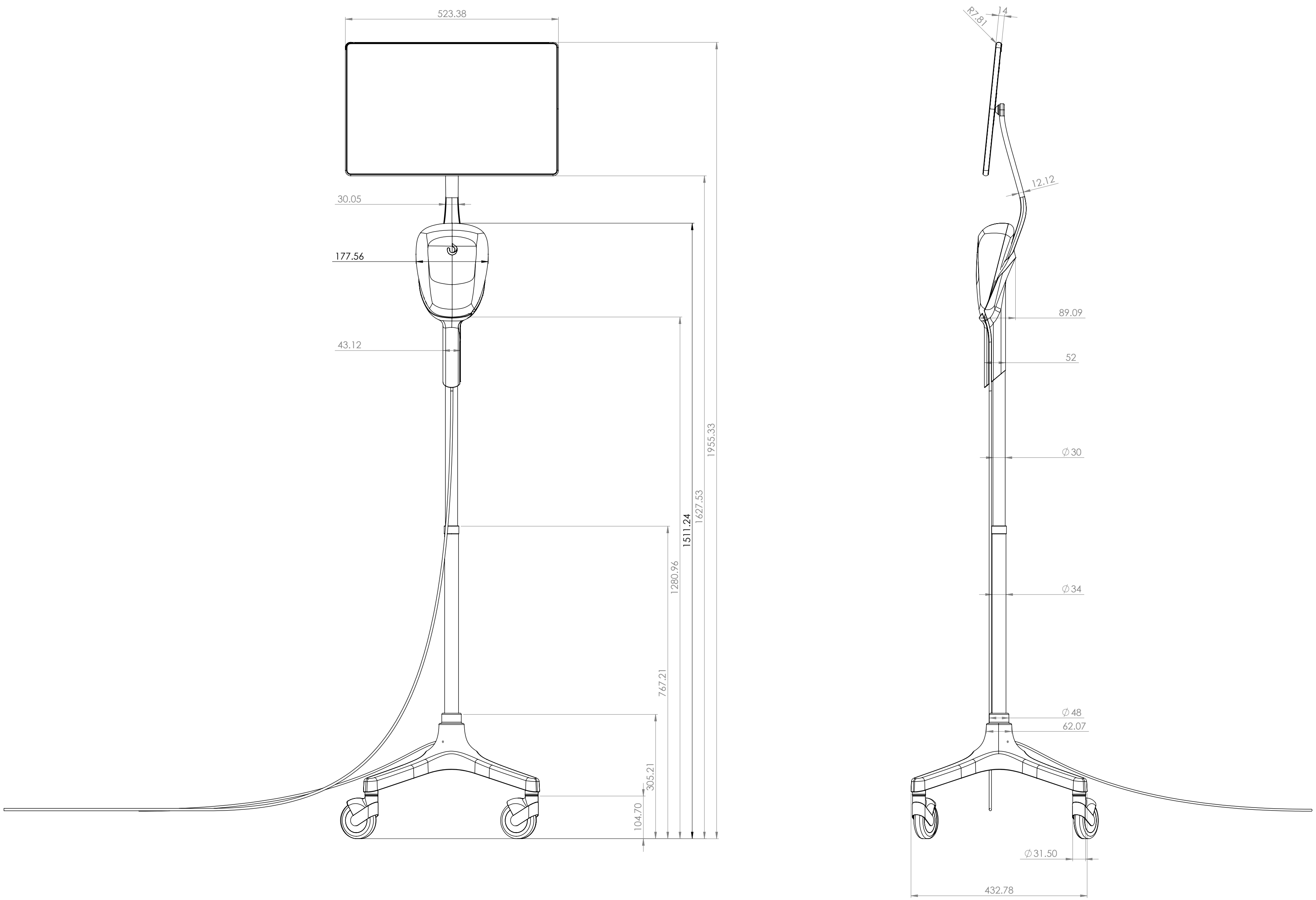
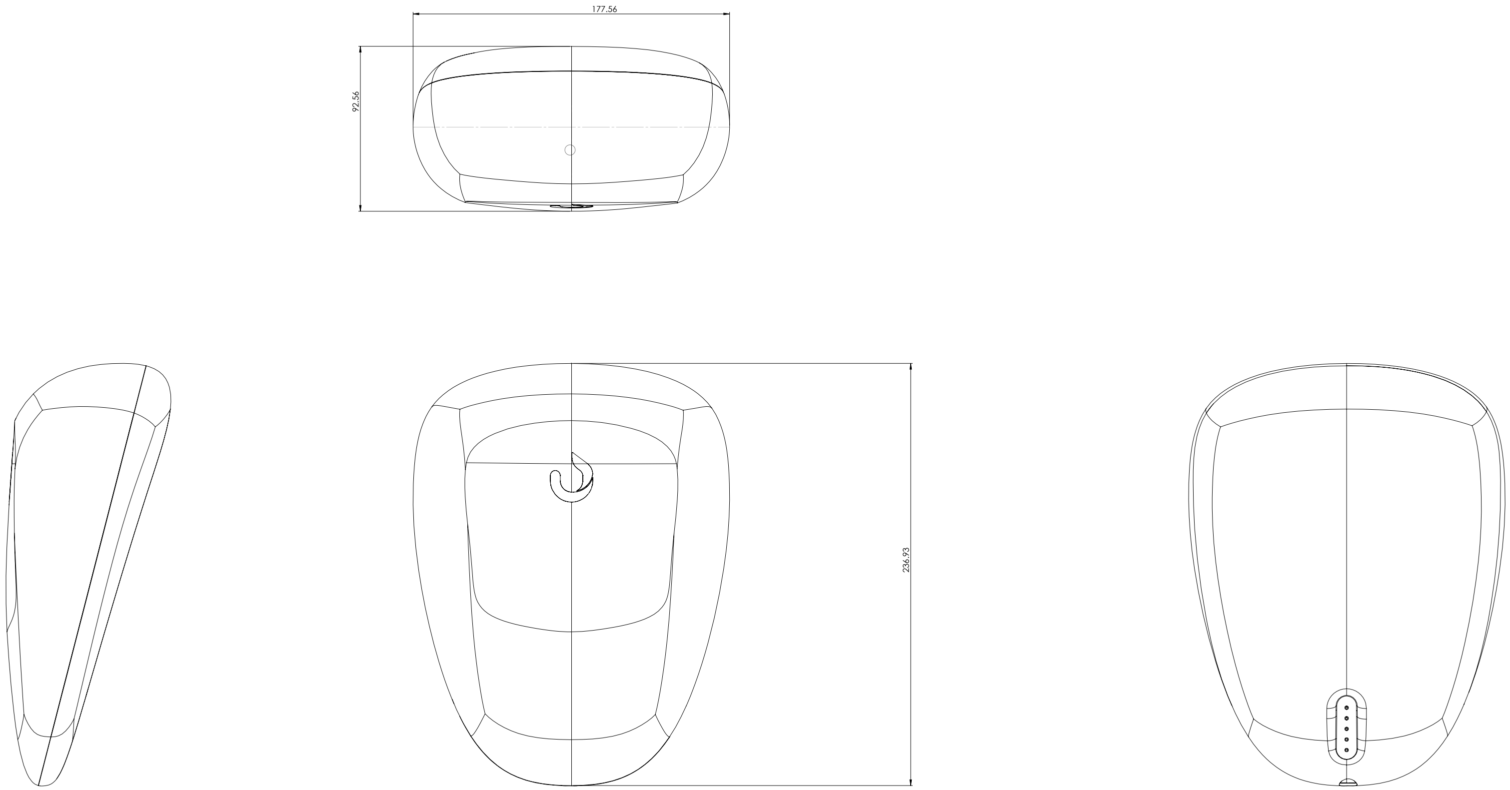
APPENDIX

Appendix A: Technical Drawings





UNLESS OTHERWISE SPECIFIED:
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REVISION

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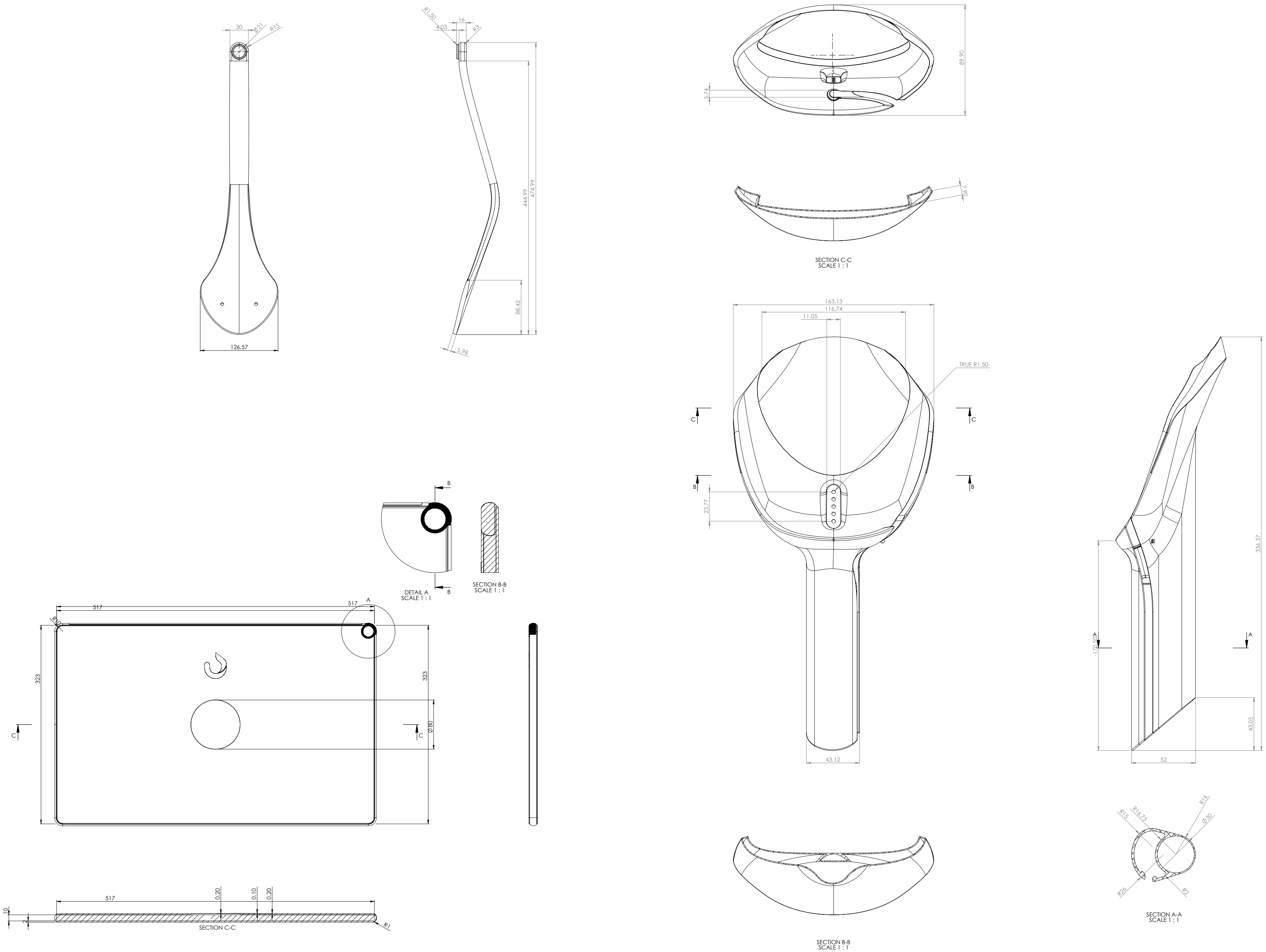

30
R15
126.57
R1.50
16
4.03
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89.90
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SECTION C-C
SCALE 1 : 1
163.13
116.74
11.05
TRUE R1.50
23.77
43.12
336.37
170.02
43.05
52
SECTION B-B
SCALE 1 : 1
R15
R16.75
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R26
R2
SECTION A-A
SCALE 1 : 1
DETAIL A
SCALE 1 : 1
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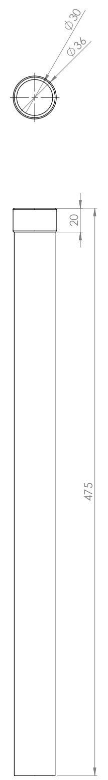

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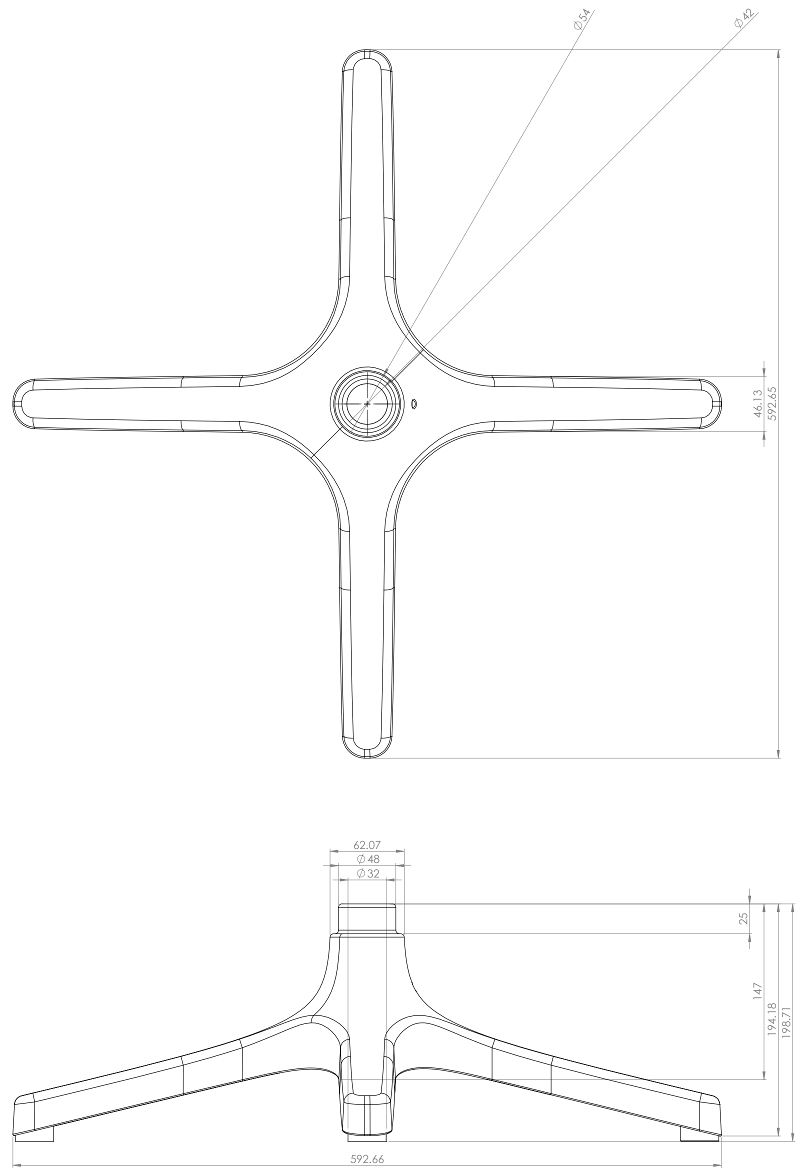

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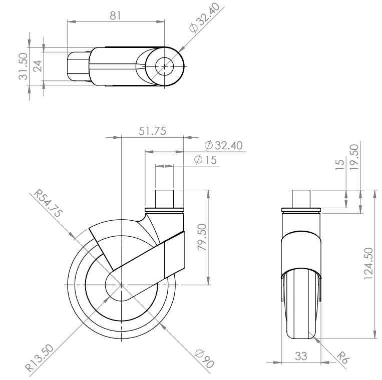

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R6

Appendix A: Stakeholders analysis

Different groups have an interest and influence in the conditions in the ICU. Groups with high interest however, do not necessarily have the biggest influence. This chapter analyses the different stakeholder, their interest, influences on the situations and influence on each other.

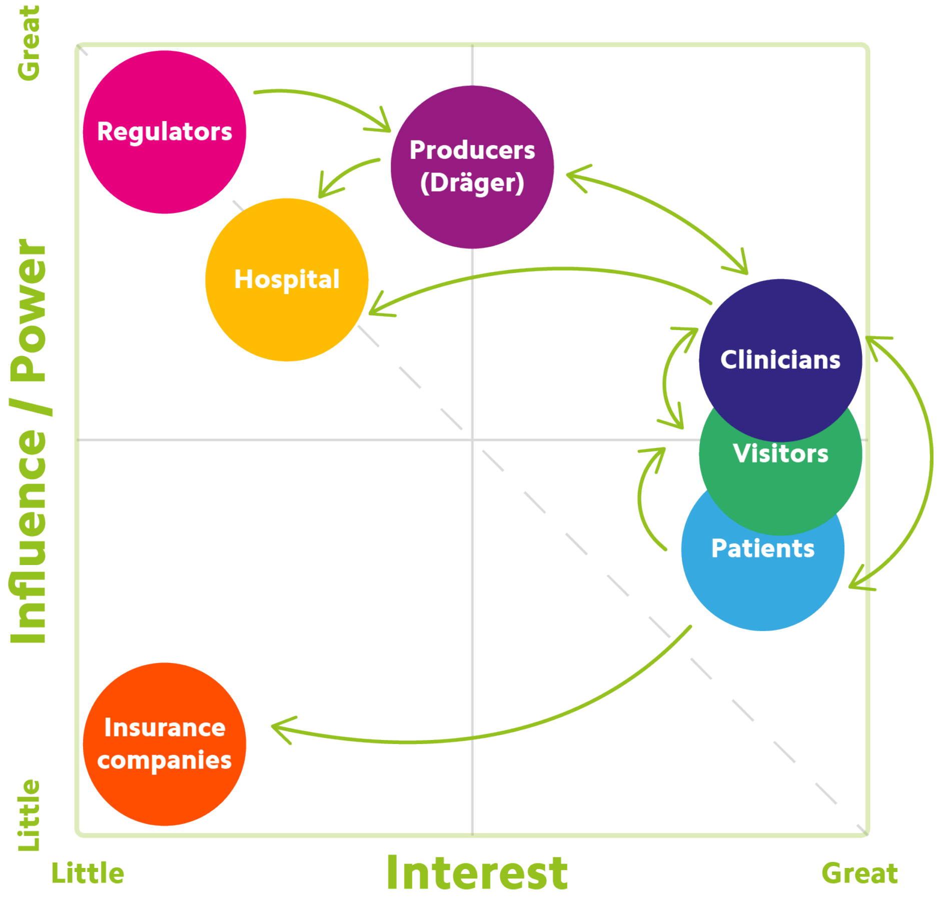
The graph shows the different stakeholders that influence the monitor in an ICU. The arrows represent the influence they have on each other.

The clinicians, patients and visitors are the more obvious stakeholders in this scenario with a high interest. They are in direct contact with the monitor and experience the negative consequences first hand. However, they do not have a lot of influence in the matter since they do not make the decisions, with which monitor to work. This decisions lays with the hospital. They choose which equipment to buy, based on the recommendations of different groups. The most important feature of the medical equipment for the hospital is the reliability. However, the hospital is being influenced by their clinicians. Clinicians can make request or even go on a strike. An improved ICU can result in less overworked nurses and less errors made for the patient, which are positive for the Hospital. It leads to a better reputation and less costs.

The monitors are made by manufactures. Those are the ones that have a direct influence on the changes of the monitor. There are small differences in the products between different brands and without the competitive market there is less need to innovate and change for them. The hospitals however, are working together with manufacturers to see which changes are possible to improve the working conditions for nurses and recovery conditions for patients.

There is one group with even more influence, the regulators. The regulators approve or disapprove products. They decide what products can be sold and what not. Starting next year it is not only illegal to sell products that are not approved, but also use them on patients. Hospitals then are no longer able to innovate themselves. However, the regulators interest is low because they do not bother with possible improvements and advantages, or try to change anything themselves.

The last one in the graph is the insurance company. When the ICU environment is improved it could lead to shorter recovery time which saves medical costs. This is advantageous for the insurance. Insurance companies furthermore sometimes fund such projects to improve their image.



Appendix C: Concept ideas

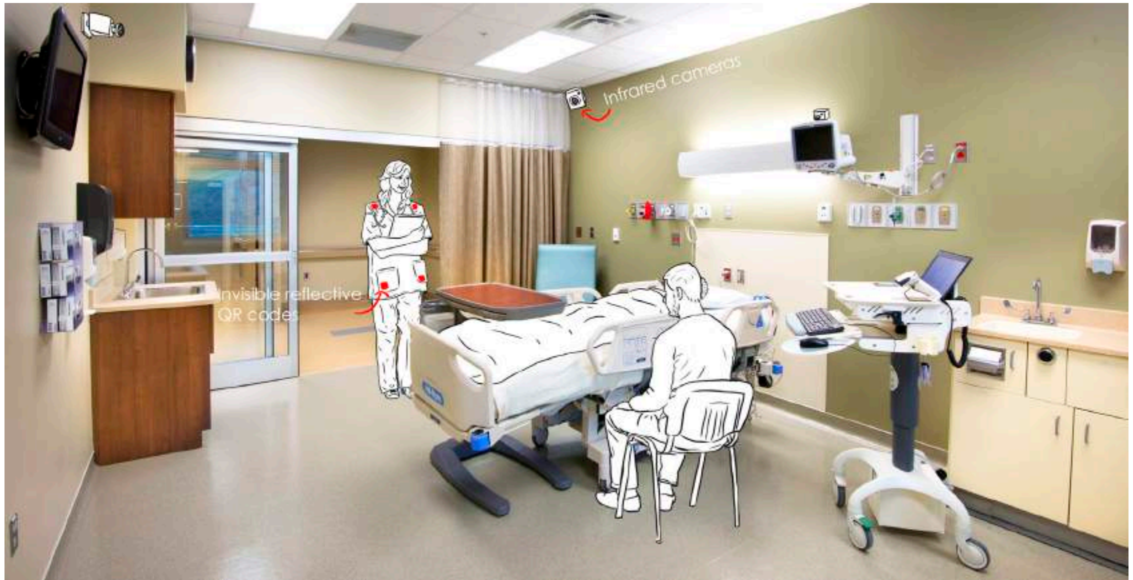
Multiple ideas have been established that can be used to achieve the target goal. In this parts several of these ideas are explained, however, no decisions have been made to further develop in the next phase. Also, the exact workings of the different concepts might change during the second half of the project.

QR IR stamp

The QR IR Stamp combines infrared reflective paint with an IR camera setup to track clinicians based on an 'Invisible' tag placed on the existing clothes of the clinicians. This tag is only visible with an infrared camera and therefore does not interfere with the workflow in any way.

The system works by first detecting people based on their thermal image. Once someone is detected the IR camera looks for any tags visible on each person. By placing multiple different stamps on each clinician the system can Identify each clinician without 'counting' them twice(if multiple cameras can see one clinician) and this also reduces the probability of people blocking the tag.

QR code

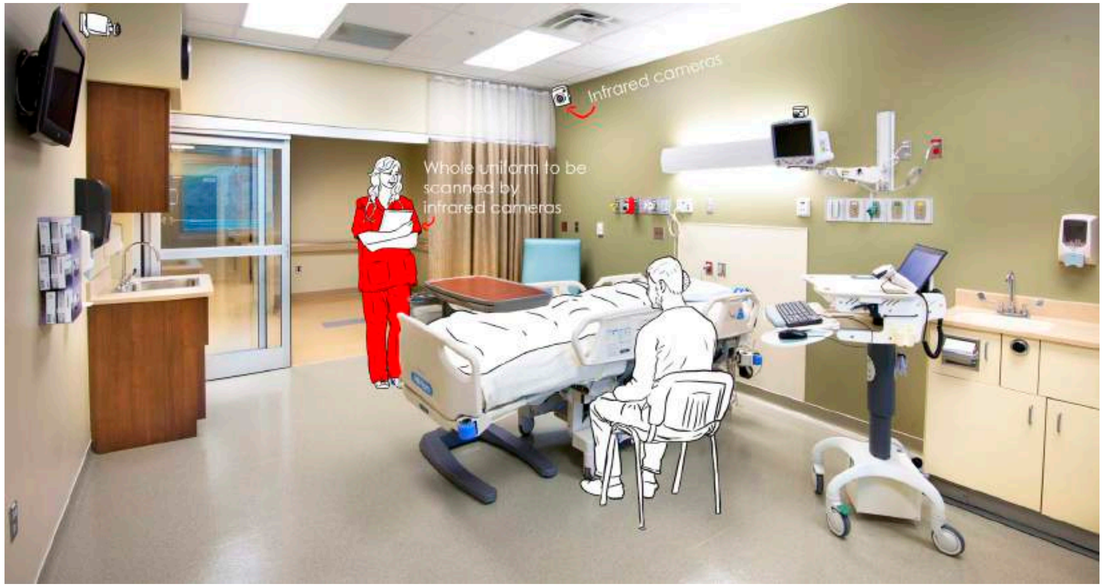


QR stamp on clinicians is recognizeable by Infrared cameras

What infrared camera sees

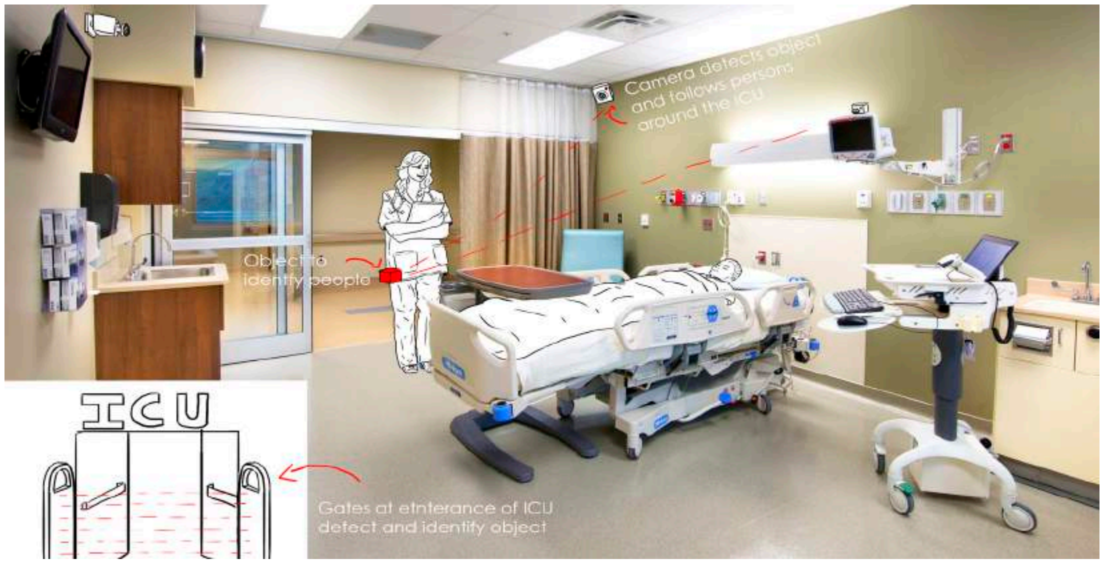
Ultiform

Ultiform works in a similar way as the QR IR stamp, the only difference is that separate clothing is provided instead of working with the existing set. This ensures that a QR code can be integrated with higher precision and durability, however, this also means that it requires a complete swap with the existing hospital uniform and is thus a more expensive system.



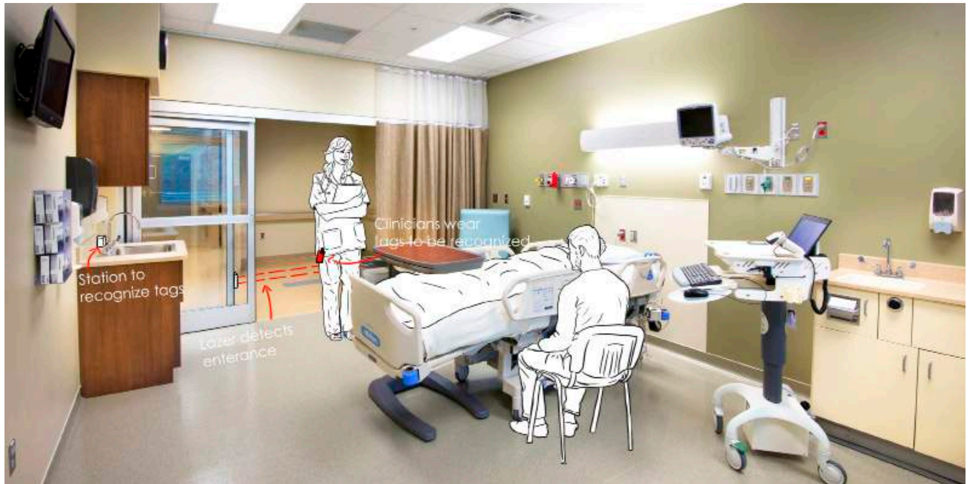
Pinch Go

Pinch go is a similar concept as the 'Amazon go'. With the Pinch go everyone who enters the ICU is identified by a still undefined method(can be cameras, cards tags etc.). After identification, a network of cameras collaborates to track the position of each person based on feature tracking technology. The main system then interprets the positions and tells each monitor of the entire ICU what to display. The entire system requires no effort of the clinicians but can be perceived as rather intruding.



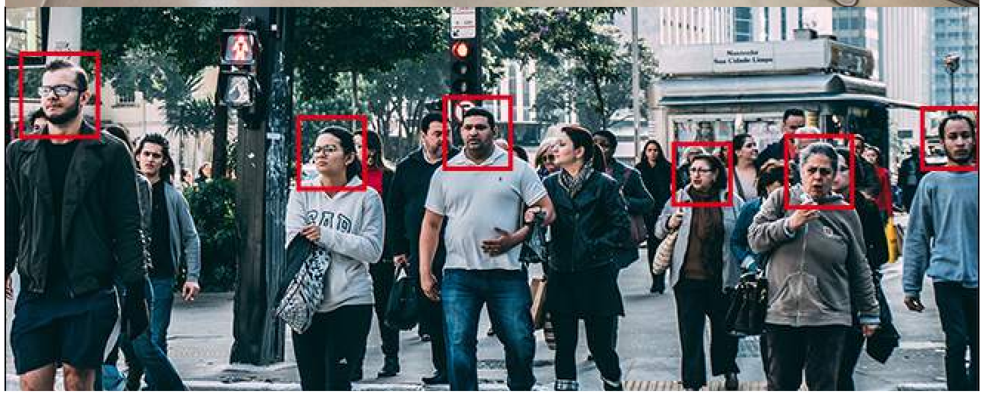
RFIDea

RFID tags are assigned to clinicians within staff ID card/ pen/ uniform, which can be detected by the readers installed inside the ICU. People entering and leaving the room are detected by the system using laser/ infrared or another simpler sensor. The system categorises the people into clinicians and visitors by searching for whether there are tags detected, then, the monitor changes its behaviour. This saves the hassle of giving out tags for the visitors. While there is a risk of the electromagnetic field may interfere with some of the medical equipment. Using active RFID where the reader emits a less intense electromagnetic field that does not affect the other medical equipment should be a promising option.



Identicam

The 'Identicam' is a more local implementation of camera usage in the ICU compared with the Pinch GO. This setup requires at least one camera in every patient box with preinstalled software capable of detecting people. Here each person is detected in the rooms themselves, thereafter a distinction is made between visitors and clinicians(by using feature detection for example). There is also a possibility to train a new object recognition model which can differentiate between visitors and clinicians in on go, but this would require a huge data set and can become very time-consuming. However, this method is less intrusive than the pinch go since it does not require constant monitoring of each individual in the ICU. Also, this sort of model can be programmed to become better over time



Beacon

The Beacon concept is similar to the previous one. The difference is rather than using RFID to detect the clinicians, this concept uses Beacon technology, which uses beacons installed in the room to detect the clinicians' mobile phones.The advantage of this concept over RFID is it can use the personal smartphones from the staff to detect the beacons, which does not require a specific tag for them.

Image 3.5.12: Location of Bluetooth tags is nowadays used to find keys, based on distance between both Bluetooth parts.

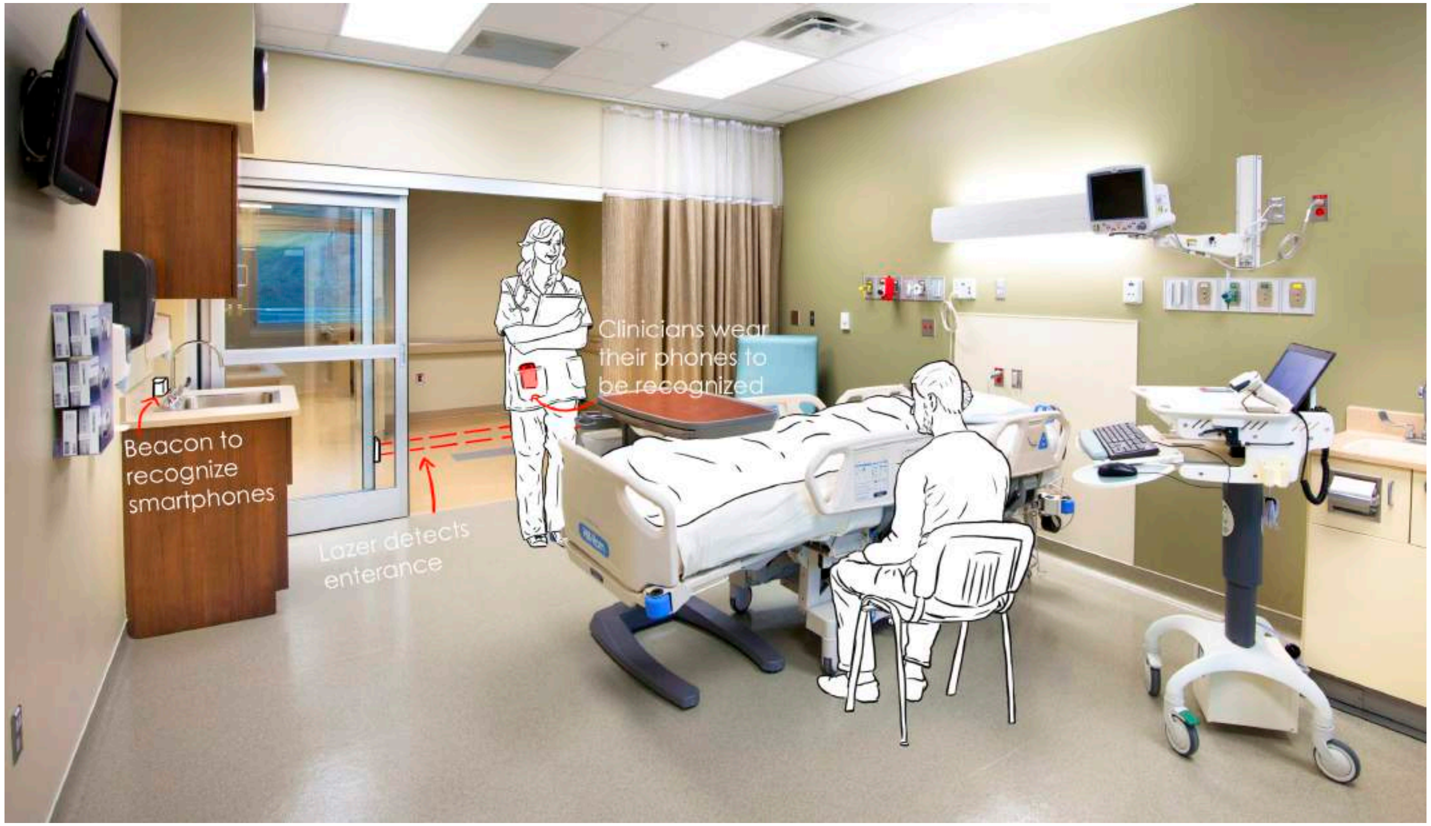


Image 3.5.12: Bluetooth from clinicians phones is detected by beacons

Appendix D: Ergonomics Research Paper

Effects of Lighting conditions inside hospital ICU on patient recovery and rest

Boschma, D; Gębala A; Gurram, N; Schuit, D; Wang, S; Wang, Y. - Delft University of Technology

Introduction

Patients within the ICU often have a lack of deep sleep, or REM sleep, as stated in Weinhouse, G's Bench-to-bedside review from 2009. Which can be caused by different reasons, such as the noise, lighting conditions or internal factors such as stress and pain. (Miller et al. 1976, Swada et al. 1996, Ersser et al. 1999, Raymond et al. 2001). Since research is done about the influence of noise and how to reduce this, this paper focuses on the influence of light on a patients rest in the ICU. The results gives insight in how to minimise the patients disturbance during their time in the ICU.

In Erasmus Medical Center, lighting conditions in the ICU are regulated centrally and change over time to simulate a correct day and night rhythm. Which is done in the hope that the patient still has a sense of time. Light is an important environmental factor in the regulation of the normal circadian rhythm (as said by Teus van Dam, head technical ICU department of the Erasmus MC on 19th of March 2018 during an interview).

Current nursing research has given the topic of lighting minimal study. Lighting in patients' rooms is easily controlled by the bedside nurse simply flipping a switch. The potential effect that light has on patients' health and positive outcomes could make this simple act one of great importance." (Dune, 2010)

However, this cycle of day and night doesn't result in a full, dark, night since the clinicians have to check the patients well being regularly. Furthermore, even when the patient is alone in the patient box the room is still illuminated by several monitors and other equipment that surrounds them (figure 1).

Figure 1, Empty ICU.

"Although patients may appear to sleep in hospital, it may not be refreshing or restorative. Therefore, poor sleep can have serious detrimental effects on health and recovery from illness" (Raymond et al. 2001). An improvement in the lighting conditions would therefore be desirable.

This research covers the preferred lighting conditions in the ICU and the difference between those in order to develop a monitor that better suits the sleeping needs of the patient. The different lighting conditions are measured in multiple ICUs in multiple hospitals in the Netherlands.This is done with a LUX meter that measures the light intensity during night and day and at the patient's bed and close to the monitor screen.

Method

For this study the light intensity of different ICU's is measured using a LUX meter (model EXTECH HD450).

The measurements are taken at specific locations inside different patient boxes:
At the patients headrest (ideally without the patient)
Right in front of a working monitor

The measurements incorporate several different lighting conditions:
During the day and night with all the machines off
During the day and night with all the machines on
During the day and night with the machines on and lights on

The night lighting conditions are simulated by closing the blinds, since visitors are not allowed inside the ICU during the night.

The lighting conditions inside our personal rooms are also measured during the day and night aside from the ICU lighting measurements. This is due to the scarce availability of ICUs. These measurements will be used to compare the ICU lighting conditions with our own preferred lighting conditions. These measurements will only be taken from the headrest, because devices are preferred off during sleep.

Finally a literature study will be done to further support our findings.

Results

Hospital measurements

Table 1: Light measurement Erasmus Medical Centre Day.

EMC	Cold light		Warm light	
	Near Head	Near monitor	Near Head	Near monitor
Max	358	425	290	260
Min	279	410	245	241

Table 2: Light measurement Erasmus Medical Centre Night.

EMC (blinds down)	Cold light		Warm light	
	Near Head	Near monitor	Near Head	Near monitor
Max	190	292	2.2	4.6
Min	174	290	1.7	4.4

Table 3: Different light intensities different monitor modes.

EMC (blinds down)	Near monitor	
	Night mode	Day mode
Max	3.2	5.6
Min	3.2	5.4

Table 4: Light measurements Wilhelminas Childrens Hospital.

WHC	Working light	
	Near Head	Near monitor
Max	58	72
Min	35	40

Sleep preference measurements

Table 5: Personal light preferences for sleeping.

Person	Night min	Night max	Morning min	Morning max
1	0	0	0	0
2	0	0	9.2	19.6
3	0	0	38.2	107.4
4	0	0	34.2	351.15
5	0	0	4.7	79
6	0	0	20.7	174
7	0	0	3.6	68
8				

Different guidelines for the lighting in the ICU exists. During the night the guidelines say the night light should not exceed 6.5 fc (foot candles) for continuous use or 19 fc for short periods, respectively or 70 and 204.5 lux. Other than this, the regulations on lighting conditions focus mainly on the clinicians when dealing with light intensity (Guidelines for intensive care unit design, 1995).

Conclusion

Compared to the current values measured the night condition 0 is comparable and the warm light condition which would be used when a nurse comes in and takes care of a patient. The working light has a lux value of 58 and therefore is still right according to the guidelines.

Even compared to the bedroom measurements, the conditions are similar to preferred night and morning conditions.

Discussion

When looking at the gathered results the lighting conditions within the patient box seems to be fairly well regulated, but lack key aspects for optimal patient sleep.

The difference between day and night settings roughly translate to the measured preferred settings. Without any lights on the ICU is dark (0-6 LUX) and with the lights on it is as bright as day (241-425 LUX). However, the ICU in Rotterdam showed the usage of a harsh cold (blue) light, which, if used during the night shift, could greatly disturb the patients sleep.
Besides the daylight lamps, the light emitted from the monitors contains blue light. Blue light helps human body to regulate its night and day mode, using hormones. (It's Okay To Be Smart, 2015).
Therefore, the blue light from the monitors irregulate the bodies day and night cycle.
Furthermore, the brightness of the screen compared to its environment brightness is higher.
The brightness of a screen is correct when it is not illuminating its environment like a small lamp and thus has a LUX intensity roughly equivalent to its surrounding (Suzuki, 2000).

Also, within the ICU are a many screens. As shown in the figure 2, the ICU monitor is close to the patients head (left), along with multiple other screens (right). According to the research done by Falbe in 2015, this has a negative effect on the patients sleep.

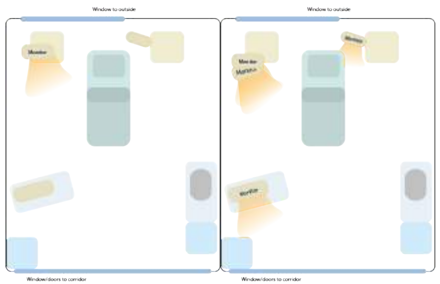


Figure 2, Monitor position in ICU.

Since the monitors are close to the patients, the blue light of monitors affects the patients sleep. The study therefore confirms inadequate lighting conditions inside the ICU regarding the positioning of monitors. Reducing the blue lightwaves the monitor emits and, if necessary, replacing them with warm, red ones could be part of the solution (Czeisler, C. A, 2013).

The results of the research show that the display brightness of the monitor is higher than its surroundings especially with the light off. And thus has to be reduced to fit its environment properly(LUX near monitor is higher.

The main problem of lighting inside the patient ICU arrizes during the night shift when the clinicians need to be inside the patient box. Clinicians need light in order to do their jobs but this results in irregular room illumination during the patients sleep. Ideally the patient's sleep needs to be uninterrupted but the use of current lighting would be too disturbing.

Recommendations

Many factors influence the lighting conditions inside an ICU. The ICU is not only an environment where a patient requires lots of rest but also one where focus and concentration is expected from the clinicians. An overall ideal lighting condition is therefore not easily stated However, it is possible to change certain parts within the ICU make it better suited for the patient.

A recommended lighting setup would contain local lighting for the clinicians night shift to ensure both their own visibility/focus/concentration and the patients rest.

This can be partly achieved using a screen that senses the light intensity itself and regulates it accordingly. This is already done in most telephone screens and thus seems to be an easy to implement option.

Furthermore, the screens and room lighting should have minimal blue lighting during the night.

Research improvements

During the research the different possible lighting conditions were measured. However, it was not measured how those different lighting conditions were used during an actual night shift. Which would give more accurate insight in the lighting conditions during a patient's night in the ICU.

Furthermore, we were limited to measuring in two different ICUs. To get more global results the measurements should have been done in more ICUs. This was difficult to do due to the critical situations of the patients and hospital regulations.

Therefore, this research serves as a start for a more indepth research on the lighting conditions in the ICU and the solutions that are viable within the ICU environment.

When looking at the result afterwards, we came to the conclusion that the measured values were a bit off. Recommendations on lux with different work environments recommend far more lux when doing work like drawing (1000 in comparison with the 350 of the current daylight condition). Therefore, it seems like the measurements taken are not in comparison with the real world. However, we were able to compare the different measurements to each other since we used the same conditions throughout the research.

Further research can be done about how the nurses currently regulate the lighting during the night. What percentage of the time the lights are actually turned off. Since the results show that ideal lighting conditions can be achieved in the ICU, this is the part where disturbance could be lowered. Whit that research more precise solutions can be found on how to reach ideal lighting conditions during the night without interrupting the nurses work, or giving them extra tasks and responsibilities.

Summary

In short, the light of the ICU in general should be reduced to a maximum lux of 70, as the guidelines suggest and lower whenever possible. With the current ICU, this is possible to achieve when the lights are turned off. The monitor itself should be design so that it turns of when not in use, and thus not disrupt the patients sleep, or at least be dimmed to match the brightness of the environment, which would also be optimal for the nurses and the blue light waves should be suppressed and replaced by warm light. This to not match daylight, because then the body will act as if it is day which has negative effects on the quality of sleep.

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Appendix E: Sustainable Impact of Ultimo

Group 21. Intensive Care Alarms (Critical Alarms Lab)

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Figure 1 Patient bed in Intensive Care

/Abstract

Pinch studio developed a smart monitoring system, the UltiMo. The UltiMo alters the monitoring screen in the ICU based on who is in the room. It silences the alarms when a patient is alone, provides easier to understand information to visitors and give full data and information when a clinician enters the room. With this system, Pinch studio aims to reduce alarm fatigue and Post-intensive care syndrome. Improving the well-being of patients, visitors and nurses. The UltiMo consists of an improved version of the current monitor, introducing an LED screen and several sensors. These changes affect the sustainable output of the monitor. In the end, the positive effects of the new monitor outweigh the negative effects and the monitor is considered sustainable, especially on the human capital.

/Introduction

Critical Alarms Lab is developing a new Intensive Care Alarm System that aims to remove all unnecessary alarming sounds from the patient box. The project includes various groups working on parts that build towards a silent ICU. Our team is responsible for the UltiMo system that changes the monitor's behaviour to whoever is in the room. Silent when the patient is alone and fully functional when clinicians enter.

This project is focussing on the sustainability part of the UltiMo project. There are three pillars in sustainability study: planet (natural capital), prosperity (manufactured and financial capital) and people (human and social capital) (Ashby, 2012). The UltiMo is focussed on the well-being of the patient, visitors and clinicians. Therefore the focus of this project is on the human capital. Based on this the prime objective and articulation, stakeholder analysis and fact analysis are carried out.

Step1 /Objective & articulation

In this chapter, the objective of this report is explained. Everything done is for reaching this goal.

Table 1 Articulation and Prime Objective

Articulation	Prime Objective	Scale	Timing
Implementing Intelligent ICU monitor (ULTIMO)	Reduce patients' Post-Intensive Care Syndrome (PICS) and clinicians' alarm fatigue	ICUs in The Netherlands	By 2025

Articulation:
To implement an intelligent monitoring system in ICU to users' perception of the monitor (patient, visitor and clinicians).
Prime Objective:
Reducing the alarms within a patient room has been done with the intention to reduce alarm fatigue in clinicians and thereby increasing their efficiency as well as reducing the post-traumatic stress in the patients due to the excessive sound.
Scale & Time:
We plan to successfully equip all the ICUs in the Netherlands with Intelligent monitors (UltiMos) by end of 2025. The Netherlands counts 84 ICUs with an average of 16 monitors, thus 1344 monitors in total. We estimated time of 2025 based on the development time which is around 2 years plus around 5 years to get FDA approval which is necessary for all medical equipment.

Step2 /Stakeholder analysis

Different groups have an interest and influence in the conditions in the ICU. Groups with high interest, however, do not necessarily have the biggest influence. This chapter analyses the different stakeholder, their interest, influences on the situations and influence on each other (figure 2).

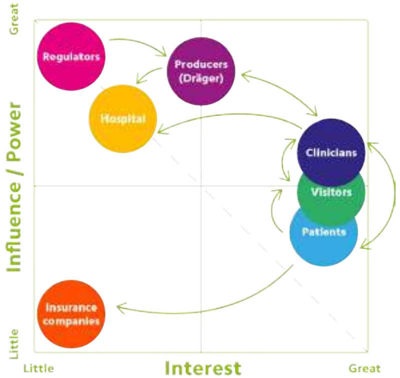

Figure 2 Stakeholder diagram

The graph shows the different stakeholders that influence the monitor in an ICU. The arrows represent the influence they have on each other.
Direct users:
The clinicians, patients and visitors are the more obvious stakeholders in this scenario. They are in direct contact with the monitor and experience the negative consequences first hand. However, they do not have a lot of influence in the matter since they do not make the decisions on which monitor to purchase.
Buyers:
The hospital determines which monitor to buy. The most important feature of the medical equipment for the hospital is the reliability. However, the hospital is being influenced by various groups. Clinicians can make a request or even go on a strike. Happy workers and the improved ICU can result in less overworked nurses and fewer errors made for the patient. These are a positive effect for the Hospital. It leads to a better reputation and fewer costs.
Manufacturers:
The manufacturers are the ones that have a direct influence on the changes of the monitor. Since differences between various brands are minimal and the competitiveness of the market is low, there is little need for innovation. However, brands do tend to work together with and are influenced by hospitals to get contracts with them.
Regulators:
To be able to sell the monitors, the manufacturers need to fulfil the requirements of the regulators. Starting next year it is not only illegal to sell products that are not (FDA) approved, but also to use them. This makes it harder for hospitals to innovate themselves. The regulators' interest is low it is a purely business endeavour of approving or disapproving products based on rules, facts and figures.
Others:
The last one in the graph is the insurance company. When the ICU environment is improved it could lead to shorter recovery time which saves medical costs. This is advantageous for the insurance. Insurance companies furthermore sometimes fund such projects to improve their image.

Not included is our client, critical alarms lab. They actually do not have anything to do with the product, like using or producing. Critical alarms lab wants to inspire the medical world and show possibilities. Their interests are already represented by the various other groups, mostly the users. They try to work with all the parties on the possibility to fulfil the needs of the various groups. This way they influence various groups to take action and make necessary changes.

Step 3 /Fact-finding

MATERIALS and SUPPLY CHAIN
To discuss the sustainable influence of a product, it is important to look at the various materials and components. Below the bill of material is shown.
BOMs for a unit of the proposed articulation

Table 2 Bill of Materials

ITEM NO		PART	MATERIAL	WEIGHT(Kg)	QTY
1		LED-DISPLAY	Bought-in display	0.787	1
2		CHASSIS	Stainless Steel (Aluminium)	0.5	1
3		ENCLOSURE	ABS	1.5	1
4		BUTTONS	ABS	0.01	3
5		POWER SUPPLY UNIT	Bought-in PSU	2	1
6		MOTHERBOARD	Bought-in PCB	1	1
7		SPEAKER			
		Magnet	Ceramic Ferrite	0.3	1
		Coil	Copper	0.1	1
8		CONNECTORS	Stainless steel	0.02	10

9		FASTENERS	Stainless Steel	0.01	30
10		LED LIGHT	Bought-in LEDs	0.025	4
11		CABLE AND WIRES	Bought-in	0.1	4
12		SENSOR MODULE			
		PCB	Bought-in PCB	0.2	1
		Enclosure	ABS	0.4	1
13		Battery	Bought-in	4.5	1

The supply chain of these materials and components is considered secure. Most parts of the monitor are sub-assemblies. The industries producing those parts are secure, stable and can be purchased regularly. As long as the business partners, transportation and personal security are carefully dealt with, the supply chain should be secure (Raghavendran, 2013).
However, according to CES, some of these products contain critical materials. The LED panel, Power Supply Unit, motherboard and LEDs contain five weight% of materials considered on either the EU or US critical list.
The other materials used are common, such as stainless steel and copper. Those have a high production and consumption around the world and a stable market. According to CES EduPack 2017 materials used in the monitor origin from:

- ABS: USA, China
- Stainless steel: China, Japan
- Copper: Chile, USA
- Ceramic Ferrite: China, Japan
- Bought PCB: China, United States, The Netherlands,
- Bought LED: China
- Bought Cables/wires: China

Table 3 Human well-being in countries of material origin

Nations	Death Penalty	Rule of Law Index	The Good Country Index
USA	Applied	91	20
China	Applied	45	64
Japan	Applied	88	19
Chile	Abolished	88	26
Netherlands	Abolished	97	3

The scope is to implement in all 1344 ICUs of the Netherlands. Therefore 1344 UltiMos need to be produced, which is an acceptable number considering the material stock in the globe (Nice, 2017). It would be beneficial to produce it within or at least close to the Netherlands. However, materials then need to be shipped towards the Netherlands. The heaviest material, stainless steel, is currently manufactured within the Netherlands so it shouldn't be a problem. Using their steel it is important to monitor where they get their steel from.
At the end of the monitor's life, the manufacturing, Dräger, has a recycling guide created for each part of the product, explaining the recycling potential for all of the components which customers can refer to. In terms of our design of the monitor, adding the sensor parts to the guide will bring more components to the system which will make disposal and recycling of the parts more difficult.

2. ENERGY

The UltiMo is a monitoring system which Is constantly on, monitoring who is in the room and sending patient values to pagers and the ward. In 2016 there were 86.000 IC patients with an average stay of 1,1 days (Nice, 2017). This means around 94,600 days of monitoring yearly spread across all 1344 IC monitors in the Netherlands. Each monitor was therefore used for about 70 days. A monitor is used for 10 years with a 2 years warranty. The Dräger monitor requires 80W to operate (so 288kWh). During their lifetime a monitor uses an average of 15500MJ during their lifetime.
Monitors are mostly connected to the power outages and the Dutch energy net, during transportation of the patient or a power outage, the monitor uses a Li-ion battery to stay powered. Sources of the Dutch energy are shown in the table below.

Table 4 Origin of Dutch net energy

		CO2 intensity in kg/kWh (fuel)
Gross Generation (TWh)	98.6	
From gas	67.1%	0.35-0.5
From coal	15.6%	0.9-1.1
From wind	7.5%	0
From biomass/gas	1.1%	0.06-0.2
From nuclear	1.6%	0.06-0.07
From other generation	7.1%	n.a.
Final Consumption (TWh)	120 (est)	

3. ENVIRONMENT

The environmental impact of the new monitor is compared to the conventional monitor using Eco-audit. As can be seen in figure 3, the materials require around 6000MJ, the current monitor slightly less. The current monitor also has lower energy consumption during manufacturing, which in comparison to using and material, is neglectable. During use, as can be seen, the UltiMo saves around 2200MJ. Which is roughly the energy needed to produce the materials.

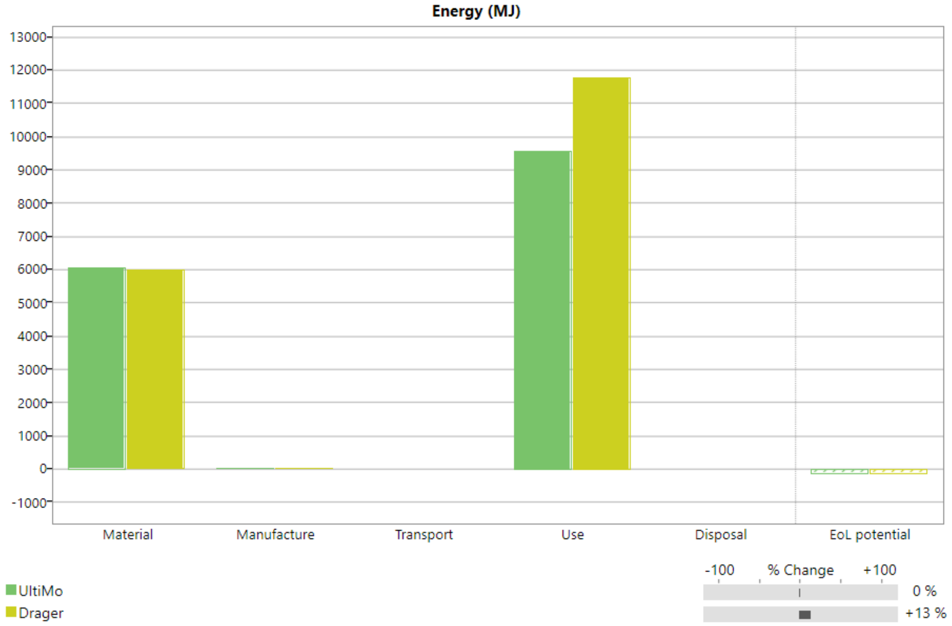

Figure 3 Energy usage current monitor and UltiMo

The carbon footprint has a similar figure (4). The carbon footprint is the amount of carbon dioxide released into the atmosphere as a result of the activities of a particular individual, organization, or community. (Time for a change) It is measured in Kg of CO2.
In terms of material requirement, Ultimo and Dräger release about 580 and 570 Kg of CO2. During the usage, however, the carbon footprint of Dräger is substantially higher, 780, compared to Ultimo's 640. So in total, UltiMo release around 130 Kg CO2 less than Dräger.

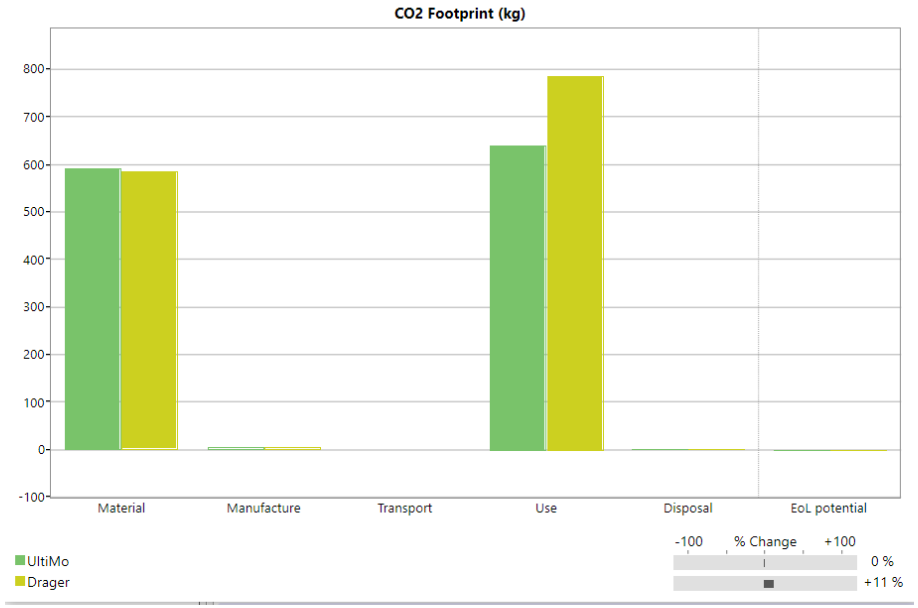

Figure 4 CO2 Footprint of current monitor and UltiMo

The UltiMo does not improve its environmental sustainability using fewer materials, it needs more. The screen is larger and extra components are needed. However, it saves energy during its lifetime due to the reduced amount of time the screen is on and the reduced time a patient is in need of constant monitoring (improved well-being).
Furthermore, the sustainability could be improved by encouraging the recycling and use of recycled ABS of the enclosure. This is currently not done at Dräger. Dräger does use so-called "commuter" packaging systems for many years. These environmentally friendly reusable packaging solutions "commute" between suppliers, production, logistics as well as customers – helping them avoid large amounts of wood and cardboard waste.

The use of LEDs uses organic materials which predominantly are carbon-based. Similar to inks to dye fabric. They are in principle abundant and inexpensive but may have limited negative impact on the environment.

4. LEGISLATION and REGULATION

The medical field is subject to a multitude of legislation and regulations. These mainly cover patient safety during use of the product. Aside from this most medical products are bound to the same legislation as other electronic devices(the implementation period is sometimes extended for medical equipment).

European Medicines Agency (EMA)
EMA is a European Union agency for the evaluation of medicinal products which is responsible for a certification. It is responsible for the protection of public and animal health through the

scientific evaluation and supervision of medicines. The legal bases are Art. 127 of Directive 2001/83/EC (medicinal product for human use) and Art. 93 of Directive 2001/82/EC (veterinary medicinal products). (European Medicines Agency)

Medical Device Directives
IEC 60601-1 are technical standards for the safety and essential performance of medical electrical equipment, published by the International Electrotechnical Commission. They are required for bringing new medical devices to the market in many countries. The European version is EN 60601-1. The device needs to be CE marked to indicate compliance with applicable European Medical Device Directives. (Medical Design Standards for Power Supplies).

Alarm standards
IEC 60601-1-8 - it governs what medical devices with alarms have to do for audio and visual indicators of alarms. IEC 60601-1-8 defines the pattern of alarm sounds, the flashing rate and colours of visual alarm indicators. In that regard, it supersedes BS EN 475, which to date has been the most widely adopted standard for alarm enunciation on medical devices.
ISO 60601-1 also describes the mechanisms by which alarms can be silenced or disabled. In addition, it suggests icons for use in resetting, silencing, or disabling alarms (see Figure). These icons are suggested, but not mandated, by IEC 60601-1-8(MDDI Online, 2018).

Figure 5 Alarm icons medical devices

Data collecting legislation
An ICU continuously monitors a patient's wellbeing. All of this data is usually stored on a hospitals networks so that clinicians can access it from a central station. This sensitive data has to be stored securely and should not be made public(EDPS, 2018). The UltiMo also registers who is in the room which should not be stored, besides a temporary database that ensures proper working, to ensure user privacy.

Packaging and packaging waste directive: This limits the amount of packaging used and encourages the use of environmentally sustainable materials.

The restriction on hazardous substances directive(RoHS): This directive bans certain substances like lead-based solder mainly used in electronic components.

Waste Electrical and Electronic Equipment (WEEE II): Under WEEE II, EU Member States must achieve collection rates of 45% beginning in 2016 and collection rates of 65% by 2019. Producers are responsible for recording the weight of the electronic components and, in principle, for financing the recovery and disposing of it.

Energy using Products directive(EuP): intends to reduce the environmental impact of electrical and electronic products. It also requires an environmental assessment of the product from the producers and the manufacturer needs to advise the user on the most environmentally sensitive usage.
Batteries Directive: Although primarily focussed on battery producers this directive also includes parts that impact products that incorporate them (Vaughan, A., 2009).

Even though medical sector requires less imminent changes all regulations will eventually also have to be taken into account when designing it. More regulation is expected in terms of sustainable medical equipment. These include, but are not limited to: higher collection rate of electronic waste, reduced usage of toxic substances, more demanding legislation regarding the use of sustainable materials and cradle to cradle design.

5. SOCIETY
The new sensing technology doesn't require any interaction with a user and will not exclude users without certain knowledge or skills. The new system, however, requires additional maintenance within the hospital. This can be done by a new team or the current team learns a new skills. On the manufacturer's side, a developing team and expert team to control the network has to be set up. The production process is more complicated due to the added sensor components. As a result, new working places will be created. Dräger produces their products mainly in Germany, Netherlands, Canada, USA and China. Promotions and hiring are well regulated and done legally and does not use forced, compulsory or child labour during their manufacturing process. We assume that the created wealth within Dräger will be evenly distributed.
Due to the efficiency, the UltiMo saves money over its lifetime. We assume that the hospital will put this to good use somewhere else within the hospital.

The UltiMo aims to improve well-being of nurses as well as visitors and patients. The visitor's and patient's needs were recognized to be silence, calmness and understandable information. The needs are addressed in the system aby implementing a visitor mode.
It aims to silence alarms and simplify the screen when there are no clinicians around. It gives clarity to understand information to the visitors, which makes them feel less confused and stressed. The decrease in alarms decreases the post-traumatic. However, the absence of the complicated screen and alarms could clash with cultural or societal norms. Users are accustomed to the complicated technical screens in the ICU. Now that they don't recognize the screen or know how the UltiMo works, they might think the monitor doesn't work properly. Therefore some explanation might be needed from the nurses to assure visitors that patients are monitored at all time.
The complete project will reduce unnecessary alarms and aid nurses in their work so that they feel satisfaction, fulfilment and feel like they are in control of the situation.

6. ECONOMICS
The thing the hospital is most interested in is that the monitor works. That it is reliable and easy to clean to stay hygienic. The new monitor and system will benefit the hospital in economical ways. The new LED screen will be more durable, therefore the monitors can be used longer before they need replacement. (see previous parts) Furthermore, the new system is expected to: reduce patients recovery time (Schmid F 2013); reduce the number of nurses being overworked and suffer from stress-related sickness; and cause fewer errors because of the decreased alarm fatigue (Winfrey, J, 2017), all reducing costs and possibly saving lives
However, the hospital equipment is expensive and hospitals need to cut their costs. They get funding from the government (de Nederlandse Zorgautoriteit) which they distribute throughout the hospital (Wikipedia). When the monitor costs more, the extra money needed has to come from somewhere else.

Currently, the monitor costs about 20.000 euros (interview with the head of ICU at Erasmus). The increased price of the new monitor is hard to estimate and cannot be done at the moment since choice on the sensing system has not been made yet.
The Dutch government does stimulate sustainable projects and initiatives with various regulations. There is the MIA regulation, where you can decrease taxes when you invest in sustainable equipment, such as the new monitor. Other funds companies can get when they invest in a social project in a third world country and in an upcoming economy (Sprout). These funds for investing, are more related to the manufacturer of the monitors (Dräger) and less to the hospitals. When Dräger produces it so that it invests in third world countries and upcoming economies they get funding. These funds might help in decreasing the price of the new monitor.

Lastly, there is a new trend developing in hospitals, green hospitals. Including more green in hospitals and create a positive environment. Dräger could advertise the monitor to suit this new trend, with a sustainable and positively produced monitor(Dhillon 2015).

Step 4 /Synthesis

From the facts in the previous chapter, a synthesis matrix was made, which is shown in the figure below. Below that the different facts are stated, divided into the various areas.
The Synthesis Matrix:

		The three capitals		
		Human capital	Natural Capital	Manufactured Capital
The six sectors	Materials	MAT5 (+)	MAT2 (-) MAT4 (+)	MAT1 (+) MAT3 (+)
	Energy	ENER1(+)	ENER1 (+) ENER2 (-)	ENER3 (-)
	Environment	ENVI1(+)	ENVI3 (+)	ENVI2 (-)
	Legislation	LEGI3 (-) LEGI2 (+)	LEGI1 (+) LEGI2 (-)	LEGI1 (+)
	Economics	ECO2 (+) ECO4 (+)	ECO2 (+) ECO3 (-)	ECO1 (+) ECO3 (-)
	Society	SOC1 (+) SOC2 (+)		SOC3 (-)
	Synthesis	+7	+1	0
		Good	Good	Bad

Figure 6 The Synthesis Matrix

MATerial:
1: Components are sub-assemblies and can be purchased regularly – stable market.
2: Some materials contain more than 5 weight% of elements that are on either the EU or the US Critical list.
3: The stress on the supply chain is an acceptable number considering the material stock in the globe.
4: Aluminium alloy will be the main metal materials in the monitor – more sustainable than steel.
5: The monitor will be manufactured close or in the Netherlands to minimize transport.
ENERgy:
1: Reduced of patient recovery time reduces energy usage.
2: Additional energy consumption for manufacturing when replacing (old/current) machines.
3: More energy used for different components.
ENVIronmental:
1: UltiMo consumes more energy (material and manufacturing) but saves enough during its lifetime to more than compensate.
2: The energy required for the materials for the UltiMo are slightly larger than for the current monitor.
3: In total, Ultimo releases 130 Kg of CO2 less than Dräger.

LEGIslation:
1: Legislation encourages recycling of medical equipment and the usage of durable materials.
2: Medical Data cannot be saved ensuring patient privacy but limiting problem detections due to big data collection.
3: Current legislation doesn't allow silent alarms.
SOCiety:
1: UltiMo will contribute to human well-being, national and personal self-esteem and pride.
2: The disposal and recycling of the product are less exploitative.
3: Due to the number of components and dependence on all parts of the system, UltiMo has a lower resilience than the current monitor.
ECOnomical:
1: A more durable LED screen increase initial cost but saves money over time (less frequent replacement and energy usage reduced).
2: A silent ICU will reduce alarm fatigue which reduces recovery time and improves clinicians work conditions.
3: Increased cost of monitor causes less money available for something else in the hospital.
4: The new monitor contributes to Green hospital environment which improves hospitals with environmentally friendly solutions.

Human Capital
The main aim is to improve the workflow and environment of clinicians and recovery of patients. Therefore, we are mostly concerned with the well-being of both clinicians and patients. The new monitor is designed to empower and increase the self-esteem of clinicians. It is inclusive because it aims to better inform the visitors which result in them becoming less anxious and more focused on the patient. The patient's recovery is reduced due to fewer alarms and better care from the clinicians. However, current legislation discourages this improvement which makes an actual implementation difficult.
The new monitor will contain more components than the current one such as sensor parts and cameras, which will make the manufacturing process more complicated. More working places will be created and bring opportunities for employment.

Nature capital
Finite resources have to be used in the production of the UltiMo including aluminium, ABS and several precious metals inside the electronic circuits. Existing monitors might be replaced before the end of their lifetime by a better working, thus sooner setting them aside as waste. UltiMo uses a couple of sensors in addition to the existing monitors. These sensors are general embedded electronic parts. So there is no substantiation effect on biodiversity and ecosystem compared to the existing conventional monitors. UltiMo monitor aims at improving the well-being of patients besides saving energy.

Manufacturing capital
The new, smarter monitor requires extra components that use energy. This at first results in negative effects on the cost and energy usage. However, it is balanced by the use of the improved products like the LED screen, which reduce energy and increase lifetime. This reduces costs in the long run.
The current legislation encourages the recycling of medical equipment. This should be taken into account when designing how the monitor enters and leaves the market. This can positively affect the environmental impact of the monitor. This is more of an opportunity than a given fact.

Since the costs are increased because of the extra components and newer electronics, the monitor requires a bigger portion of the hospital's budget.

/Conclusion

Our project is less concerned about the environmental impact and is more about how to improve human well-being. Which is stated in our prime objective. The synthesis shows that the human capital is well represented by the new monitor. The well-being is improved and visitors are better informed. The well-being of the patient is improved by reducing alarms and the nurses can feel more confident and empowered by the new monitor. These aspects improve the perception of users on the monitor, which is the articulation and the aspects reduce the alarm fatigue and post-intensive care syndrome.
However, the inclusion of the extra sensors and cameras brings some complications. For example, the price is increased and the manufacturing gets more complicated, which may require more natural resource. By implementing a better LED screen and smarter usage of the monitor we try to balance the negative effects of the extra parts.

In the end, we are not able to precisely evaluate the prime objective since the product is still in early development. So specific information on its exact carbon footprint, bill of materials and use cannot be determined. However, the product does show a promising environmental impact since patient and clinician well-being would be greatly increased while also having the possibility of speeding up patient recovery time and thus save both energy and money during its lifetime.

/Reflection

The project mostly focussed on the well-being of patient, nurses and visitors. Therefore the prime objective was to improve this well-being and reduce alarm fatigue and Post-intensive-care-syndrome. This was aimed to do by changing the view on the monitor. On the one hand, having fewer alarms to make people feel nervous and overwhelmed. On the other hand, making the monitor looking more friendly so they make the users feel at ease. This is not done by improving the monitor sustainability per se. However, by implementing new and improved materials and components, the new monitor turned out to be more environmentally friendly than the current monitor, despite the added components. However, since the prime objective and articulation were reached other than by changing components for the better it was difficult to make full use of this procedure to improve the project. In hindsight, it might have been more useful to focus on a really specific component, like the screen, that could be improved and fully researched in this report.

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/Appendix

Further questions about society:

Does it increase self-sufficiency and resilience?
The system doesn't affect self-sufficiency but decreases the resilience. Ultimo has more functions than the current monitors but they are run automatically and the current functions ones are unchanged. In other words, the operation of the monitor by clinicians doesn't require more action but it also doesn't remove any of their duties. There is also no need for additional supervision of a system. In terms of resilience, it is less robustness because it has more components: sensors, the communication device (Bluetooth, RFID) which can be affected and influence the monitor behaviour. The manual button is integrated into the case of this situation.

Are plans in place to invest some of this wealth in the local community?
Yes. The Dräger Foundation was founded in 1974 by Dr Heinrich Dräger. The Dräger Foundation promotes science and research, especially in the area of national and international economic, social, and environmental policy. In addition, the Foundation is involved in a range of activities serving the public good of refugees in Lübeck(Germany) and the surrounding region, including short-term relief activities and long-term sustainable support of those affected, as well as in the field of medicine, music, art and culture, as well as the protection of the landscape and the environment.

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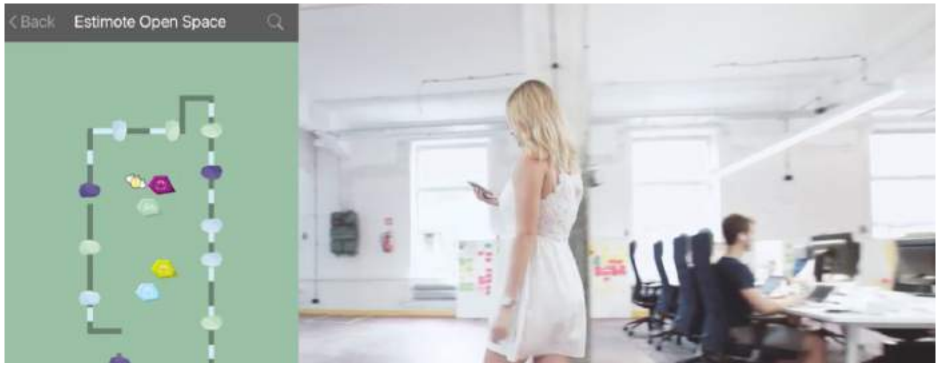
Appendix F: Sensor Research

Correct sensors need to be selected in order to create a correctly functioning prototype that can detect and differentiate between clinicians and visitors. Therefore research is needed on many different sensors that can be used to do so. Since all sensors have positive and negative aspects (like cheap but inaccurate), different sensors are evaluated and discussed in detail.

Bluetooth

Bluetooth is one of the most commonly used communication modes due to its ability to avoid interference with radio signals. Bluetooth can reach transfer speeds of about 1 Mbps. Unlike IrDA, the primary competing technology, which uses light radiation to send data, Bluetooth uses radio waves (in the 2.4 GHz frequency band) to communicate, and as a result, Bluetooth devices don't have to be in visual communication to exchange data. This means that two devices can communicate even if they are on either side of a wall, and best of all, Bluetooth devices can detect one another without the user's involvement, so long as they are within each other's range.

The indoor tracking system is one of the reliable applications of Bluetooth that can be implemented in the current system to keep tracking the clinicians in the ICU. The system is made up of a central monitoring system, the device being tracked and Bluetooth Access Points. The Access Points, in this work, are implemented applications on PCs that have Bluetooth radio adaptors connected to them. Access Points only resend the message (or signal) sent by the device being tracked.



RFID

RFID consists of small integrated-circuit "tags" that can store information and announce their existence passively through wireless radio communication to a network of RFID readers. The tags are manufactured as either passive or active and use radio waves to communicate their identity and possibly other information to nearby readers. Passive RFID tags do not have internal power, are activated by the electromagnetic field generated by the reader, and transmit information back to the reader. The electromagnetic field can cover a distance ranging from 1 to 50 cm to 10 to 30 m. Active RFID tags are operated by batteries and can broadcast information, such as identity or product temperature, without being activated by the reader.7,20 An active tag can broadcast over a distance of 50 to 100 m.

Though RFID has been easy and promising identification system, still cannot be introduced in healthcare environments due to their high-intensity electromagnetic emissions and the need for large size antenna to operate at a a reasonable distance which affects the other medical equipment.

Ultrasonic sensor

Ultrasonic sensors are based on the measured propagation time of the ultrasonic signal. They emit high-frequency sound waves which reflect on an object. There are two types of sensing with Ultrasound. Proximity Detection: An object passing within the preset range will be detected and generate an output signal. The detect point is independent of target size, material or reflectivity.

Ranging Measurement: Precise distance(s) of an object moving to and from the sensor are measured via time intervals between transmitted and reflected bursts of ultrasonic sound. Distance change is continuously calculated and outputted.

LASER sensor

Laser sensor can be used to detect the obstacles as well as measure the distance of the obstacle. It uses a laser beam to sense any obstacle that comes in the path of the beam by measuring the reflected rays. The sensor detects when the light sensor gives a high or low value when it senses a lot or less light. This could be placed near the door to detect people and count the number of people inside the room.

But to be able to detect if a person entering or exiting the room, it requires two laser sensor to be placed at a distance from each other so that the time difference could be used to identify the direction of obstacle movement.

Deep Sensor

The depth sensor uses a camera combined with an IR projector that projects a known pattern in the room. The camera then records the image and can get a depth map by localizing the specific points of the pattern that have changed scale and angle due to objects in the room. One of the major limitations of this technology is that multiple sensors cannot be used because the patterns would interfere. So, this requires only one camera to be placed inside each patient box and at a position where it could cover the whole area of the room. This also limits the usage of this sensor near the door/gate of each patient box as it may interfere with other sensors from the next patient box.

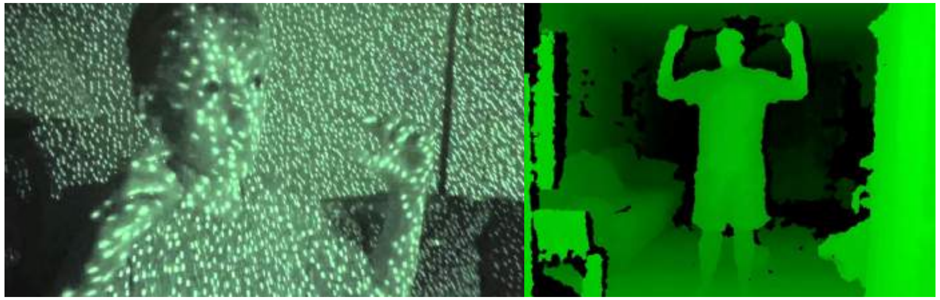
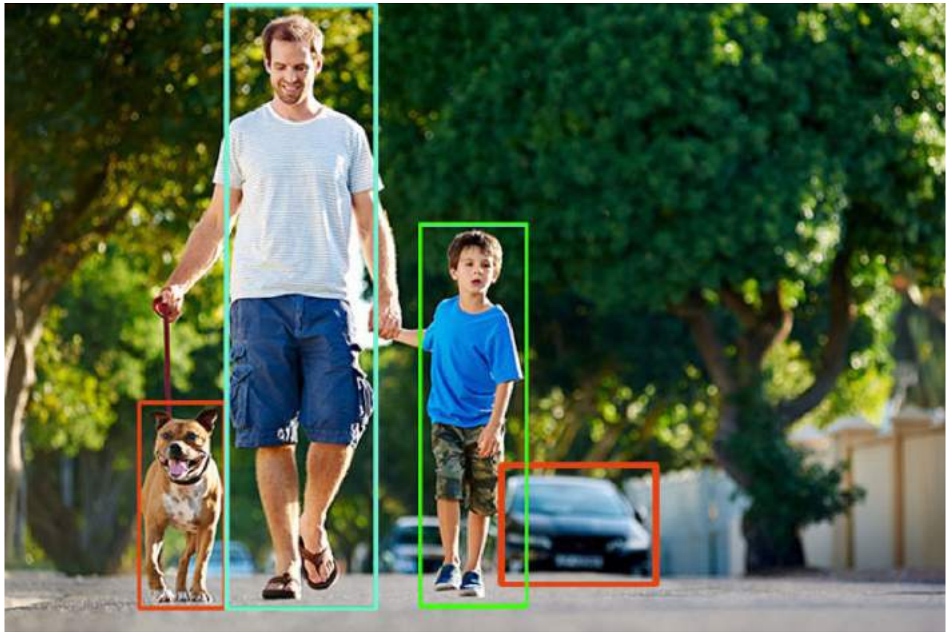


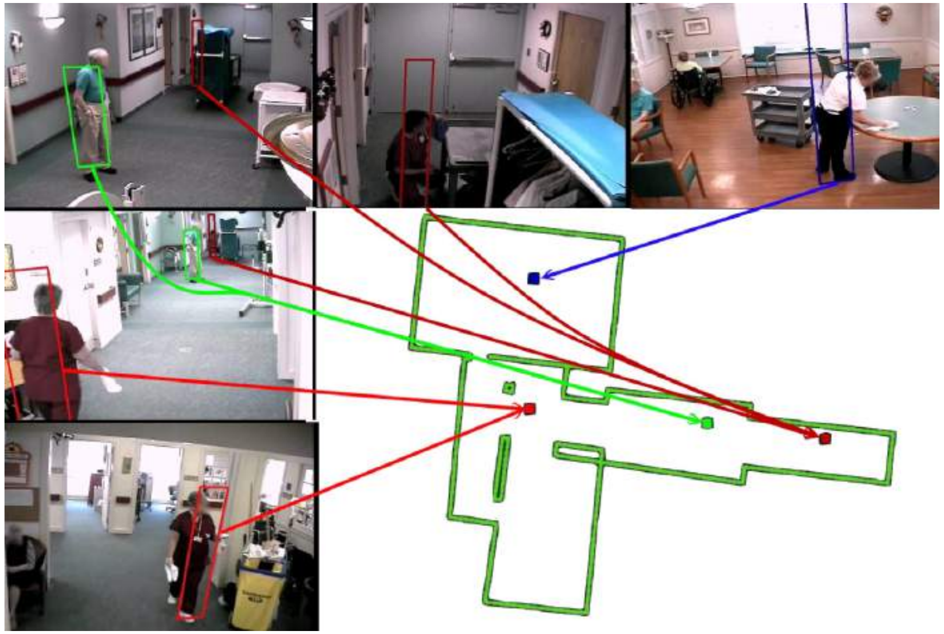
Image recognition

Object recognition can be done in a variety of ways; feature detection, template matching, machine learning, etc. All object recognition methods would require a camera setup within each ICU. These three are all capable of being used on a raspberry pi because they make use of the OpenCV python package.

Template matching takes two images: one large image and one template. In template matching the large image is searched for the spot that matches the template to a certain degree.

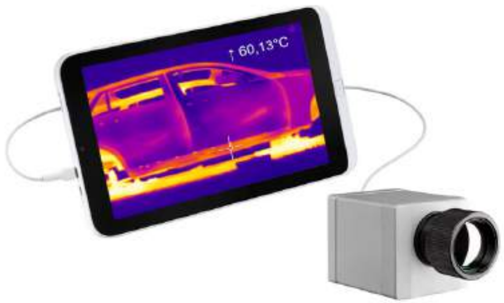


This degree of similarity can be adjusted to make the detection more accurate/ reliable. Whereas feature matching takes certain points within a template image and looks for similar orientations. Object detection uses a trained Haar cascade model to find specific features of not yet seen objects. For example, you can train it to recognise faces by providing the model hundreds of images of faces and then use this model to detect a new face in an image that it has never seen before.



IR Camera

An infrared sensor uses Infrared light in order to sense some aspects of the surroundings. An IR sensor can measure the heat of an object as well as detects the motion. The emitter is simply an IR LED (Light Emitting Diode) and the detector is simply an IR photodiode which is sensitive to IR light of the same wavelength as that emitted by the IR LED. When IR light falls on the photodiode, the resistances and the output voltages change in proportion to



Appendix G: Local Server code

Local server(javascript)

```
const HTTP = require("http");
const URL = require("url");
let state = {};
function okay(res, data) {
        let dataString = JSON.stringify({
        beacons: data
        });
        let length = Buffer.byteLength(dataString);
        res.writeHead(200, {
        'Access-Control-Allow-Origin' : '*',
        'Content-Length'    : length,
        'Content-Type'      : 'application/json'
        });
        res.end(dataString);
}
const server = HTTP.createServer((req, res) =>
        {
        let query = URL.parse(req.url, true).query;
        let id_tmp = Object.getOwnPropertyNames(query);
        let id = String(id_tmp[0]);
        if (query[id] != null) {
        if (state[id] == null){
        state[id] = {};
        }
        //let now = Math.floor(Date.now() / 1000);
        let d = Date.now()
        //let d2 = d.getDate()
        var array = JSON.parse("[" + query[id] + "]");
        state[id].rssi = array;
        state[id].last_update = d;
        return okay(res, "Done.\n");
        }
        return okay(res, state);
        });
server.listen(8000, "0.0.0.0");
console.log('Server is running on port 8000');
```

Appendix H: Agenda of the Erasmus MC new ICU visit

Agenda of the Erasmus MC new ICU visit

25.05.2018

OBSERVATION:

Look at visitor behavior; what are they doing, where are they looking, emotional status.
Look at clinician behavior, how often in the patient box, emotional status.
Observe how many sensor wires go from small drager monitor to the patient and how big are the sensor module.
Check how much is actually displayed on the screens(Graphs, figures, numbers, etc.).
The general flow, events and things that are happening in the ICU, like alarms going off people walking in and out.
One of us could, if possible, join the doctor on its round, look what is happening, what they are doing during such a visit (for a context movie and general information what they need).

QUESTIONS:

Clinicians and maybe Visitors (if possible):
Visitor display (PE study):

- Questions:
    - Should we show body vital functions on a screen to the visitors?
    - What are the up and downsides of (not) showing it?
    - Could we show limited data on the screen for visitors? And what can be the possible consequences?
- Questionnaire: Can you evaluate/rate our displays' proposal? What do you think about them?

* Do you use Drager monitor for transporting patients?

Tues:

- How often do you replace the sensor modules/ or is it really necessary to give the option on interchange the sensor modules?
- Do you have an old stand (trolley) which we are able to use?

ACTIONS:

Take pictures of:

- Hall
- Patient box
- Nurse box
- Drager monitor (top, bottom, side view, small monitor)
- Sensor cables

Do measurements:

- Drager monitor(w,h,d) of both screen and stand
- Patient box entrance(w,h)
- Number of machines and cables

Appendix I: Questionnaire for professionals - Teus

Intensive Care Alarms Systems - Survey

Dear Teus, this a quick questionnaire to have a feedback on the system we designed. Here we show some pictures of the system and individual parts of it. We would like to know what does it mean to you and if you prefer any improvements to it.

To brief you about our system, we use camera and beacons as detection parts. Camera senses if someone enters or exits the patient room. Clinicians carry beacons with them. Beacon scanner is placed inside the PC. If the PC receives data from both camera and beacon scanner, it is identified as Clinician and if only camera data is received, it is identified as visitor.

Identity cards with beacons

Beacons are Bluetooth low energy stickers that send specif data to the scanner. These beacons are stuck to the identity cards. The lifetime of these beacons is one year and can be detected from a distance of 10 meters.

How well does these new card fit in clinicians' lifestyle

	1	2	3	4	5	6	7	
Do not fit	○	○	◉	○	○	○	○	Fit well

Acceptance of new cards by clinicians

	1	2	3	4	5	6	7	
Low acceptance	○	○	◉	○	○	○	○	High acceptance

Do you think beacons can be attached somewhere else on clinician apart from identity card?

- ◉ No
- ○ Other: ____

Camera on the ceiling

The camera is mounted near entrance and detects people entering and exiting

How well the camera design suite with the hospital interiors?

	1	2	3	4	5	6	7	
Doesn't suit	○	○	○	○	○	◉	○	Suits well

How does it look?

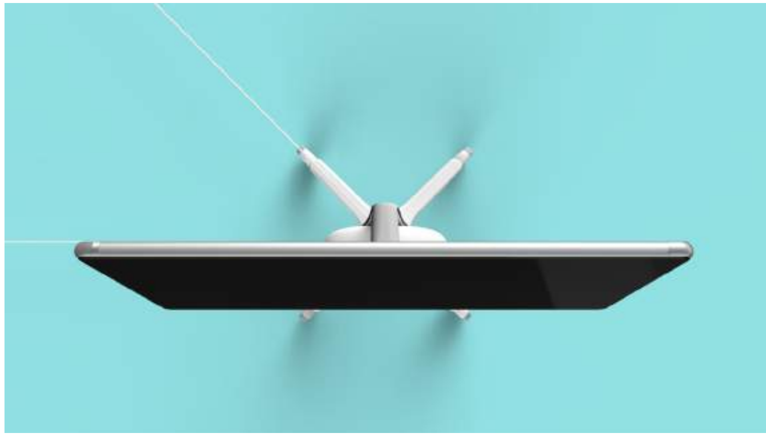
	1	2	3	4	5	6	7	
Intrusive	○	○	○	○	○	◉	○	secure monitoring

What does the design mean to you?

- ◉ The camera is spying on me
- ○ The camera is tracking me for a good reason
- ○ It doesn't look like a camera
- ○ The device is one of the interiors that i don't have to think about

Monitor design & display modes

The new infinity display has a body to screen ratio of 97%. The bezel around the screen has no button or LEDs. The scroll wheel has been shifted to the top left corner by integrating int o the monitor profile. The top part of the monitor is a long LED to indicate the alarms. the bottom part of the screen is integrated with tactile buttons internally for manual override.



How does the monitor look?

	1	2	3	4	5	6	7	
Conventional	○	○	○	○	○	○	◉	Futuristic

How do you like the scroll wheel design and its placement compared to current design?

	1	2	3	4	5	6	7	
Do not like	○	○	○	◉	○	○	○	Like

PC & basket

The PC is portable just like Drager, but now it is intelligent as it knows who is present in the patient box. There is only one cable going from the PC to the patient bed. When the PC is placed on the basked, it is automatically connected to hospital network and monitor display.

How does it look?

	1	2	3	4	5	6	7	
Non-medical	◉	○	○	○	○	○	○	Medical

What do you think about the PC having no screen and two different displays, one on the stand and the other one on the bedside?

Since we need a transport monitor it does make sense that the "PC"has a screen or simple way to connect pc to small tablet size screen while on transport

Sensor panel

The sensor panel is a cable connector to convert all the sensor cables into one single cable. This lies on the bed side and doesn't need any external power.

How important is this to convert all cables into one able?

	1	2	3	4	5	6	7	
Not very important	○	○	○	○	○	◉	○	Important

What do you think of having one cable from patient bed to the monitor?

Awesome although I am not sure if all parameters which need to be monitored can be located on 1 side of patient/ bed

ULTIMO - Overall system

ULTIMO as a system, transforms a regular ICU into silent ICU. This intelligent monitor knows how to provide a relaxing atmosphere for patient.

How helpful is this system in your work?

	1	2	3	4	5	6	7	
Not much	○	○	◉	○	○	○	○	Very much

Is there anything you would like to add?

Roling stand does not seems the best option but of course other mounting solutions can be used; In design (esp 1 cable approach) 1 thing to keep in mind some technologies do need >> power (like a blood pressure pump)

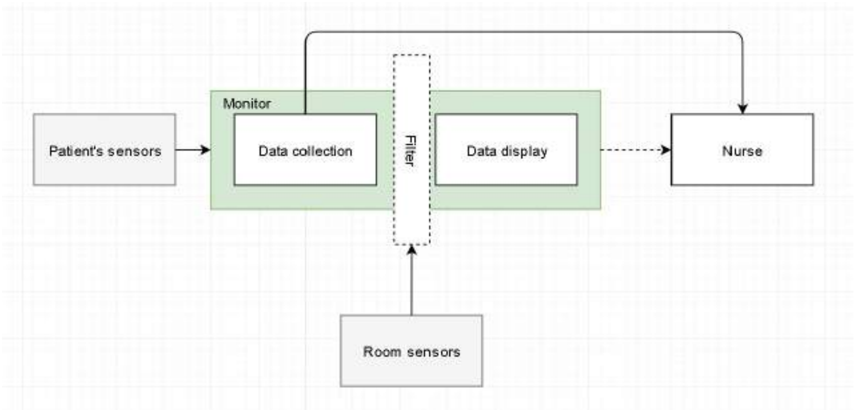
Appendix J: End of Week Briefing

Meeting 1, 15.02.2018

On Thursday, 15 of February we had the first meeting as a group with the coach and client - Critical Alarm Labs, represented by Elif Ozcan Vieira. Also Gerd W. Kortuem, from IoT and Erik Bottema, from the previous project, joined this meeting.
After we introduced ourselves to each other Elif and Erik explained the JMP project that will be the starting point for this project. The JMP project began really broad and worked on the alarms and alarm fatigue in the ICU. They explained to us that the patients in the ICU need a lot of rest and peace and quiet to sleep and heal. That's why they are positioned in the quietest part of the hospital. However, the constant beeping and alarms of the various monitors and sensors of the patient create a stressful, hostile environment. A patient that has been released from the ICU can have PTSD like symptoms for months or even years. Furthermore the nurses in the ICU can become overwhelmed and stressed due to all the beeping that's happening. They can become lost and lose focus, or stressed out and driven mad by the constant beeping. The JMP project tried to develop a system that helps the nurses as well as the patients in the ICU. Different aspects were a new system of getting notified on pagers, different sounds as alarms and muting the sound when the nurse leaves the patient's room.

Our project starts with the last part. We will focus on the monitor in the patients box. How the monitor will detect who is in the room and how the monitor reacts on those people. The ideal situation would be a monitor that lights up and gives a pleasant sounding feedback when the family comes in, displaying the data they expect and want to see. When a nurse comes in the monitor fades to a feedback for them and the monitor switches to show the nurses all the needed data. When people leave the room the sound fade out and the monitor is turned off.

Assignment interpretation



The upper graph shows our interpretation of what is expected to be achieved in this assignment. The patient is monitored by several sensors which are collected and displayed by the monitor(visuals and audio). Currently the monitor generates excessive alarms that disturb all parties involved (patients, visitors and nurses). Our job is to create/implement some sort of filter that adjusts the displayed information and alarms to whomever is in the room.The filter uses the data acquired from sensors placed within the room to change the contend on the monitor. The nurse may want the unfiltered data at his/her post so the filter is only used on the monitor in the room itself, however this is an assumption and should be further analysed. In this way the filter allows the monitor to become sensitive to its environment.
There are three types of people that can be in the room at any time. These are the patient, the visitors and the hospital workers(nurses/doctors). Because the patient is always in the room we require the system to only recognise if there are others in the room and if there are hospital workers among them. Its functionality is explained below.

Functionalities
- Detect if a person is entering the patient box
- Check if the person entering is a nurse
- Decide what to be shown on the display & when to mute the alarms
- Communicate the patient's sensor data to nurse

For the next week we are planning to become acquainted with the materials we received from Elife and make a desktop research of ICU environment and monitors. We will also try to schedule the visit to the ICU and PMB workshop.

Questions:
1. Is our interpretation of the assignment correct and what should be adjusted if not?
2. Who else would want to hear the alarms apart from nurse? (for example doctors)
3. Is it possible to schedule the visit to EMC just to observe the ICU environment in the next week?
4. Do you expect us to develop a new pager for nurse? or attach something to the existing pager, hack it? Or make a new device?
5. What control would a nurse want to have regarding the filter? Should she have more capabilities in term of adjusting the threshold of the alarm triggering at certain moments when she knows it will be a false alarm?
6. What is the budget for the project?(for prototyping, travel expenses, etc.)
7. Can we contact the ICU engineer about hacking the Draegor monitor?
8. We would like to visit Philips ICU. Is it possible for you to schedule a visit for us to look at their 'ultimate' ICU?
9. The critical alarm room on the second floor, when can we use it? Is iit open or do we need a key? Is there a schedule for the room when it's occupied?

End of the week briefing 2

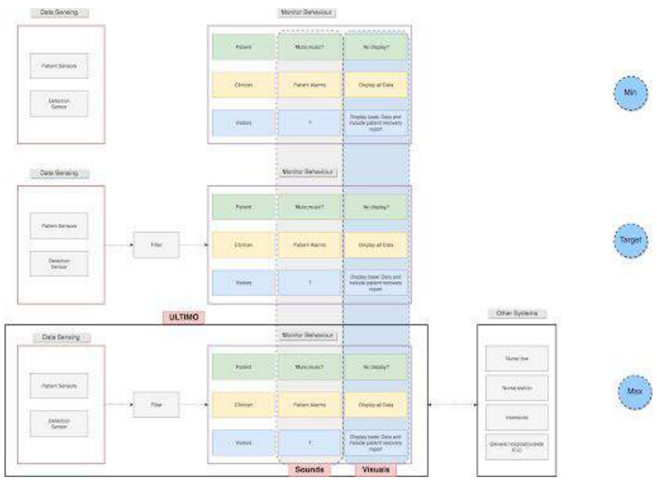
Introduction

This week we got more insights into the project and ourselves as a group.
We declared our group and individual goals. What we want to achieve during this project in terms of end product and personal growth. Furthermore, we settled on a group name, Pinch Studio, and even came up with a name for the project, Ultimo.
Furthermore we started to look into the different sensors and how we could start to test them in a first prototype. Next week we will develop this further and visit the hospital to get more insights in the environment of the product and to ask some questions we stumbled upon during the research of the past two weeks.
The Sustainability course within the university project let us think about the prime objective and articulation. How will our project be sustainable within one or more of the three pillars, people, planet or profit. The outcomes of this workshop were discussed during the coach meeting on Thursday.

<u>Project progress</u>

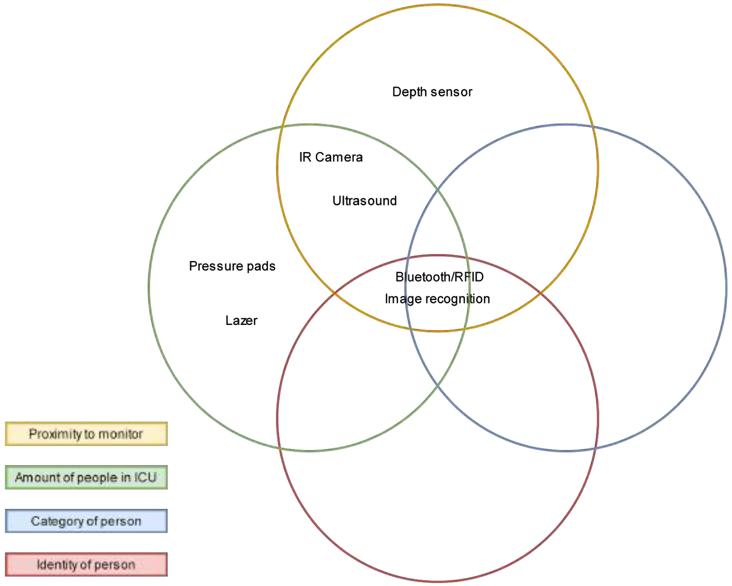
Min goal - Target - Max goal

This week we discussed the end goal of the project. We established three phases and will work on them one after the other. First we'll try to make the two systems of sensing and displaying separately (min goal). Hereafter, the two systems would need to become communicate in order to have a minimum viable prototype (Target). For now this is what we think we can achieve within the duration of the project. If we manage to complete this second phase we'll also try to have the system interact with other devices/systems in the ICU (our stretch or max goal).



Sensor graph

We started exploring the sensors which might be used in this project. The picture below shows four segments that might be useful to detect inside the patient box together with sensors that would enable the segment's implementation. These four segments include; category of person in the patient box (visitor, nurse, doctor, etc), amount of people in the patient box, identity of the person (which specific clinician) and the proximity of a given person to the monitor itself. All these things could be relevant in deciding on the behavior of the monitor any given time.The idea behind measuring proximity is to have a feature that displays particular information on the screen when the clinician approaches the monitor. We thought about adding this function to decrease the monitor brightness at night and improve the day and night rhythm. First we'll look at sensing the amount of people and their categories.The proximity and identity will be integrated after these two due to them being unessential for a correct working of the system, but could contribute to an even better regulation of the monitor behavior (for example knowing what specific nurse is where at what time could help with alarm messaging).



Coach meeting recap

This week we developed our Prime Objective and Articulations; our team Goal and personal goals and what we think would be the easiest and hardest part of this project.
These topics were discussed during the coach meeting on Thursday.
We declared our Prime Objective as “Reducing the patients’ Post Intensive Care Syndrome and clinicians alarm fatigue”. We try to reach this goal by introducing a intelligent monitor system, The UltiMo, in the Intensive Care Units.
For this project we set a scale and time period on which we focus during the sustainable expertise project within the course. This time and scale is to implement the new UltiMo within the Erasmus ICU in 2025.
Our group goals were already discussed in the previous area.
We discussed about the difficult and easy parts of the project, what will come natural and what should we be aware of. Within the group we think that the enthusiasm to work on the project will come natural. This will lead to us being able to make a prototype that can sense who is in the room. It becomes difficult when we start to connect the sensors to the monitor. The challenge is in connecting the sensors to a working and reactive screen. Furthermore it could be difficult to get everyone on the same page. That’s why we strive to keep communicating about our team goals and personal goals. Furthermore, we want to start prototyping as soon as possible, to have enough time to connect and implement both of the prototype parts into one working UltiMo.

Next week

We will start our week with two workshops: milling and drilling in PMB workshop to obtain necessary permission to use the equipment during the prototyping stage. The duration of it is 8 hours. On Wednesday we will visit the ICU in Erasmus Medical Center in Rotterdam and meet with the hospital engineer.
For next week we are also planning to research different detection sensors: the ones which we have already pointed in the graph and also try to find new ones. The capabilities and possible application of the sensors will be explored. We will also start to consider how to make the sensors communicate with each other.

Questions we want to get answers on

- What is the scope of the project? A product only for EMC or also other hospitals?
- Can you further elaborate the usage of the card system of EMC?
- Can we get a description on the future ICU of erasmus?
- Privacy issues regarding implementation of Cameras in the projects
- Legal issues using the clinicians personal phones as “pagers”?(Coach)
- Can we make pictures when visitors and do we need certain files for confidentiality?
- Can we have a floorplan of the future ICU with layout of the rooms/equipment etc.?
- How can we use the budget? Pay in advance or message you what we need?
- What particular Dräger monitor is used so that we can read up on its functionalities and workings?
- Can we contact other companies to test usability, feasibility, etc.?(In terms of IP rights)

There is also a link to all weekly briefings

End of the week briefing 3, *02.03.2018*

We had our workshops in the PMB lab last Monday. So now we are free to use its equipment when we want during the prototyping face.
Furthermore, we started with the Advanced ergonomic feasibility part of the course. During this we will test the ergonomic aspects of the product we are developing. For us it would be interesting to focus on the cognitive ergonomics, rather than the physical part. During the testing phase, there could be a possibility to also get some insight for the Product Experience part of the course.
To test the ergonomics, it could be useful to have the Dräger monitor for test subjects to interact with.

This wednesday we visited the Erasmus Medical Center where we met with the hospital engineer - Teus van Dam. He gave us the first impression of the monitor and the ICU. He was really enthusiastic about working together and helping us during the project. Giving us the opportunity to meet once a week or once every two weeks. We got to ask our questions and he told us about the possibilities of prototyping with the Dräger monitor, which are limited. We learned about the options that are included in the monitor to help silencing the alarms, like the privacy mode and the button that silences the machine for 1-5 minutes. Reality shows that nurses do not push the silence button before working on the patients and evoke sound, some do not even silence the monitor after it started beeping.
Teus explained the need for the solution of the alarm fatigue, a lot of people have tried it. Due to regulations and a strict process until legal approval, it is hard to make big changes to the system and it takes a long time to implement. For example, if you want to change the normal range of heart rate, you need to prove that the new range is reasonable and safe, which will take years.
Teus advised us to make a prototype that only influences the turning on/off of the privacy mode and work from a virtual monitor simulator. Not change anything about the connection between the small and bigger monitor.

Prototyping options:

Person detection:

Two pressure mats
PIR sensor, one sensor can sense direction of movement.
Image recognition sensor

Monitor Control:

We've found an alternative to using the dreagor monitor by using a **Raspberry Pi** together with the healthypi kit. This would allow us to prototype the monitor and actually integrate the change of monitor behaviour based on who is in the room. Specifications of this module can be found here.https://www.crowdsupply.com/protocentral/healthypi-v3 The cost of the module would be around €200,- euros and a Raspberry pi would also be necessary(~€40).

Having a drager monitor would still be advantageous in order to get acquainted with its capabilities. By using the Raspberry Pi for all the prototyping we can leave the Dräger monitor as is to ensure nothing will be damaged during our usage of it(if we are allowed to borrow one). We can also calibrate our prototype to the Drägor monitor in order to make sure our design simulates the real world. The ViMP(Virtual Monitoring Platform) Teus worked on could also be of use instead of the physical model. It would also be useful to get the monitor data of a real patient in order to get an accurate image of the things that happen in the room.

Next week:

- A worked out plan for Teus (including what do we need, steps and stages in this whole four-month project)
- Contact our IO Hospital room to see possibilities to prototype
- Deciding on the ergonomics topic
- Continue on researching sensors and start making prototype

Questions:

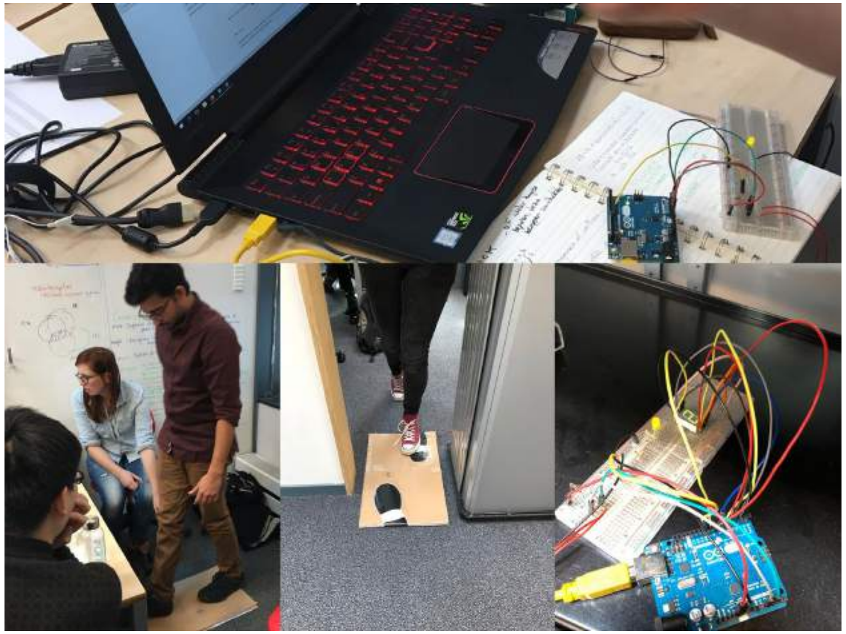
1. Can we place an order for the raspberry Pi and Healthy Pi module?

End of the week briefing 4, *09.03.2018*

This week we started building our first prototype; a simple pressure sensor that recognises in and outflow of people and counts the number of people present in the room. It is far from bulletproof, but it got us one step further in the prototyping journey. However, most of the work was directed toward the expertise areas of the course. Mainly the Product aesthetics and Ergonomics were worked on and are discussed below.

Prototyping

We created a simple people counting device that counts the number of people inside the studio using cardboards and arduino. The prototype automatically adds and subtracts based on the footsteps of people entering and exiting the room. When there is one or more people in the room, a LED lights up. And there is a single digit display to show the number of the people in the room, which can work without connecting to a computer.



Product Experience/ Assignment 1

For the Product experience part multiple monitor brands and setups were evaluated in order to get a general feel of the available products today. This is a systematic method of researching product aesthetics. Doing this allows us to make a unified design that uses Dräger's design language as a base.

One of the most interesting monitors which we found is BeneVision N22/N19 by Mindray
http://www.mindray.com/en/product/BeneVision_N22_N19.html

Advanced ergonomics feasibility/ Draft topic for study

The ergonomics part requires a short research paper to be written. We have discussed possible research areas that might be relevant to our project, both physical and cognitive ergonomics. These research areas include:

- What do visitors want to see in the patient box/ what do they do?
- How does the nature of the alarm sound change the users motivation to mute it?
- What display size is ideal for the monitor?
- How does the monitor influence the visitor, what do they look at?

Next week:

- More prototyping
- Sensor research discussion on Monday
- Afternoon in IO Care Lab on Monday
- Decision on Ergonomics research topic
- Ergonomics literature research
- 3D Scanning workshop

Monday the 19th of March, one week further, we will visit the Medical Center of Utrecht with Elif and Maurits. In that afternoon we made an appointment to meet with Teus in Rotterdam.

Questions:

- Could we be informed about any pictures and visuals shared online? We would like to prepare separate content which we are comfortable sharing with the wider audience of this project.

Appendix: We made a garden :)

End of the week briefing 5, 16.03.2018

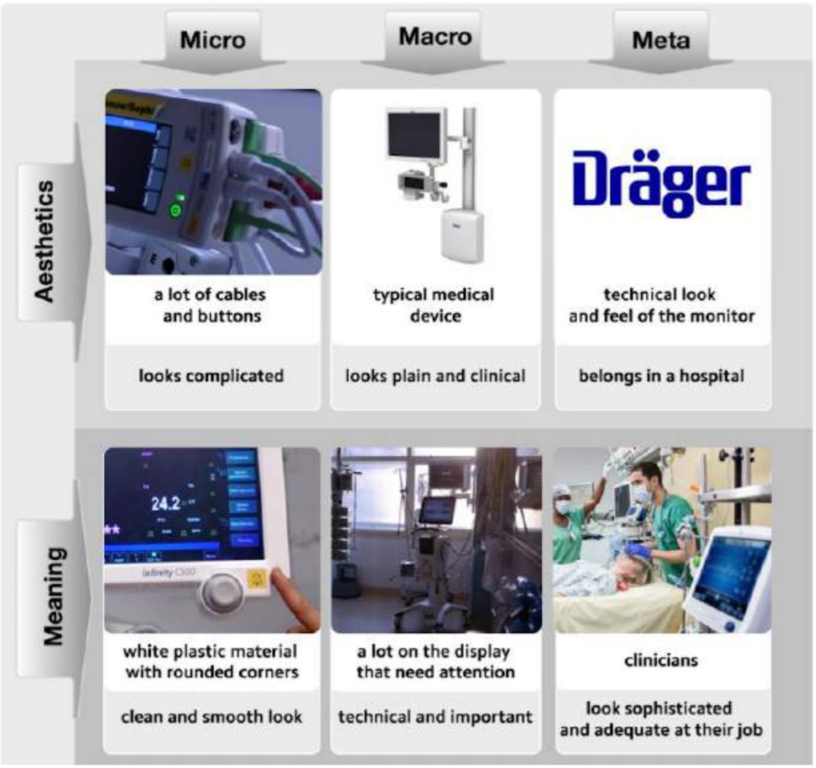
This week

This week we spend a lot of time working on our expertise areas, the different areas we tackled was the emotional meaning of our product for Product Experience, the ergonomic value of our project (regarding the influence of light) of Advanced Ergonomics Feasibilities and a Stakeholder Analysis for Sustainable Design Engineering.

Furthermore, we visited the Care Lab in IO, looked around and discussed how it could be useful for our project.

Emotional Meaning

On Tuesday, 13th of March, we had a meeting with Product Experience coach discussing about meaning and emotion to be involved in the design. We developed a more clear vision in how to incorporate this part of the course into our project.



The influence of light

To research the ergonomic part of our project we focussed on the light and its influence on a patients sleep. We set-up a research and gatherted the equipment so we could start our research next week when we visit the Utrecht Medical Center and the Erasmus Medical Center. In both hospitals we are going to measure the light intensity of patient boxes in the ICU under different conditions. This way we will see the difference and influence of turning the medical equipment on and off during the night and day. Furthermore, we measure the light intensity of the current monitors in it's different modes (night and day mode). We will use the gathered information in determining the light intensity of our optimizes monitor and prototype.

AEF Research Set up:

The Research:

We'd like to research the light intensity within the ICU patient box. Excess lighting within the ICU might negatively influence the patient's speed of recovery so measuring the intensity will be a valuable step to help and improve it. For this research we need to have access to an "empty" ICU patient box with working equipment (preferably 2 room or more)*.

Method:

We will measure the different light intensity with a simple LUX measurement device.** These measurement can be done fairly quickly since it is basically pressing a button at multiple locations within the patient box.

We will measure the light intensity at two different points:

- At the patients headrest(an empty patient room would be ideal)
- Right in front of a working monitor(that is switched on)

And the measurements are made simulate different lighting conditions:

- During the day with all the machines off
- During the day with all the machines on
- During the day with the machines on and lights on
- During the night with all the machines off***
- During the night with all the machines on***
- During the night with all the machines on and the lights on***

Results:

Received results will be presented in the scientific paper and implemented in project which is a part of the Advancet Embodiment Feasibility Course in cooperation with the Critical Alarms Lab.

*Working medical equipment would be equipment with their displays turned on. They do not necessarily make a sound or really measure anything

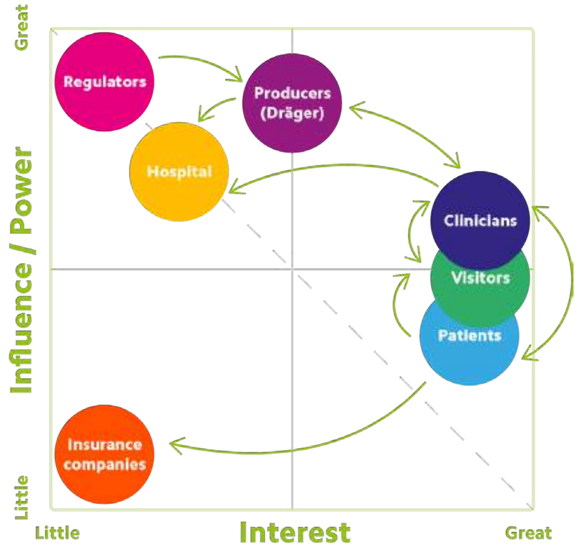
**All measurements will be done using a small LUX meter(photometer borrowed from the TU Delft applied labs). The measurements will be written down on paper.

***We will "simulate" the night by covering the windows of the patient box.

3D scanning

For Advanced Ergonomic Feasibilities (AEF) we dipped our toes in the world of 3D scanning. We learned more about the limitations and possibilities of the different methods and scanners. To get familiar with the scanners, we made some scans of ourselves. Our logo is made into a 3D rendering and printed into a 3D model and we also looked at scanning ears and faces.

Who is involved and what do they want?



Yesterday, thursday 15th of march, we followed the stakeholder workshop of the sustainable design engineering expert area. We did research on who have interest or influence on our project and what they want. We translated our findings into a stakeholder diagram that shows the influence and interest of the different stakeholders within our project. Arrows suggest influence in the diagram.

The groups with the most interest are the groups that are in direct contact with the problem and solution, the clinicians, visitors and patients. They want to have a more relaxed environment that gives reassurance. However, they have relatively little influence on the product. They can make complaints or recommendations, but their reach is limited. On the other hand, the regulators have a lot of influence. They are able to green light a new solution or shut it down. However, they are concerned with the practical and technical parts of the project and see a lot of projects during the day. They are less interested in the final advantages and disadvantages or change in the product.

This workshop also required us to research the different stakeholder areas. This lead to a few interesting insights that will be relevant later on in our project. A few of these insights are stated below.

VIsitors of an ICU patients can be very stressful and are very focussed on the patients wellbeing. The visitors however need to be well informed about the patient's status to ensure their trust in the clinicians work and decrease their anxiety about the patients health. Having visitors around the patients has a positive impact on their wellbeing and should be positively stimulated.

EMC Rotterdam aims at creating a healing environment that contributes to a patient’s natural recovery and prevents that personnel develop so-called building sickness.

Dräger sees patient monitor as a growing profitable market. They aims to improve the efficiency of internal processes, and increase the satisfaction of hospital staff.

Care Lab Visiting

We visited the Care Lab in IO on Monday. The setting of the room contains basic medical equipments which can make a patient room atmosphere. We may use the room as a context of our further user research.

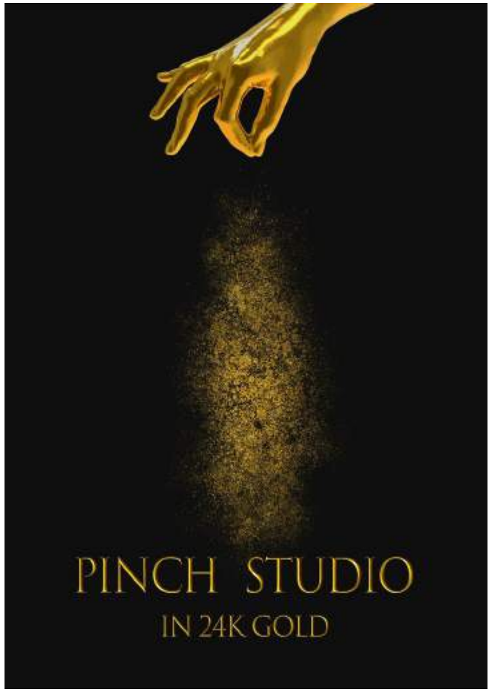
Next week

We are going to visit three hospitals. On Monday morning we have a meeting in Wilhelmina Children Hospital / University Medical Centre Utrecht and in the afternoon in Erasmus with Teus and Ryan Forde from Draeger. Aside from the meetings we are planning to conduct our AEF study there. To receive reliable data we will try to do it also in Haga in the Hague in the end of the week.

- More prototyping
- Sensor research discussion
- Literature study for the AEF paper
- Conduct a AEF study

Appendix

24K Gold version Pinch Studio :)



Garden update:
First life is showing.

End of the week briefing 6, 23.03.2018

Visiting Wilhelmina Children Hospital (Monday)

On Monday morning together with our client Elif Ozcan Vieira, coach Maurits Willemen and two other students we visited Wilhelmina Children Hospital and met with Anesthesiologist and pediatric intensivist Erik Kommen. Due to the opening of a new ICU, the hospital works on the development of a new system which will decrease the PICS and alarm fatigue. Erik Kommen shared the results of their research and gave us some feedback on our concept. After the presentation we were able to visit the children ICU and take light measurements for our AEF study.

Visiting Eramus MC (Monday)


On Monday afternoon we met with Teus and Ryan from Drager in the empty ICU of Eramus MC. Ryan did a brief introduction about the functions and usage of the monitor. He also agreed to share more information such as patient data and part of the programming codes with us in the future. Teus showed us how privacy mode works and the light settings in the ICU, as well as the real time monitor display in the nurse station. During the meeting we also managed to conduct the AEF research in the ICU in day and night mode and took measurements of light intensity respectively. After the meeting we received information on different standards regarding designing the monitor. IEC 60601-1 covers basic safety for all medical devices, IEC 60601-1-8 the alarm standard and it governs what medical devices that have alarms have to do for audio and visual indicators of alarm. In addition, we are expecting to know more about the Drager Gateway API, which is designed for this kind of research purposes and will probably make our prototyping easier.

PE (Tuesday)

On tuesday we had a discussion with Elif about the negative and positive emotions involved in the product interaction. We formulated three key emotions in each category. Each emotion is marked to the three kinds of people, Patient (P), Visitor (V), Clinician (C).

Three key positive emotions:

Trust (P V)	Look heavy, solid, clean, display informative text, arm/comforting look
Feeling of being taken Care (P V)	Indicate on status, display patient status
Confidence (P V C)	More distinct sounds, informative display, backup system

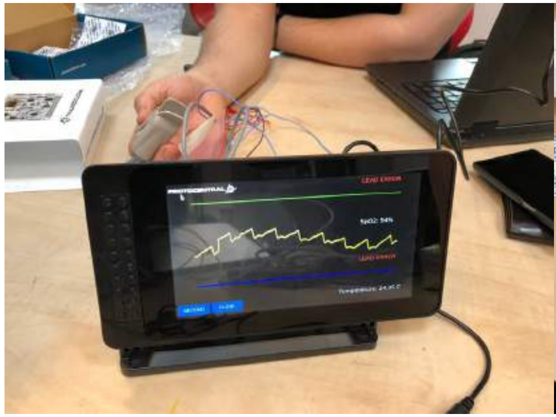
Three key negative emotions:

Uncertainty(P V)	Understandable data visualisation
Annoyed (P V C)	Reduce (false) alarm occurrence, simplify usage, improve visitor-patient communication.
Numb (Overwhelmed) (C)	Reduce the number of sound alarms, use visual alarms

AEF


Most of the data has been gathered this week. We took measurements in two hospitals and four of us have already measured the light at our homes to use them for the comparison. The literature research is complete and we are working on the rest of the scientific paper.

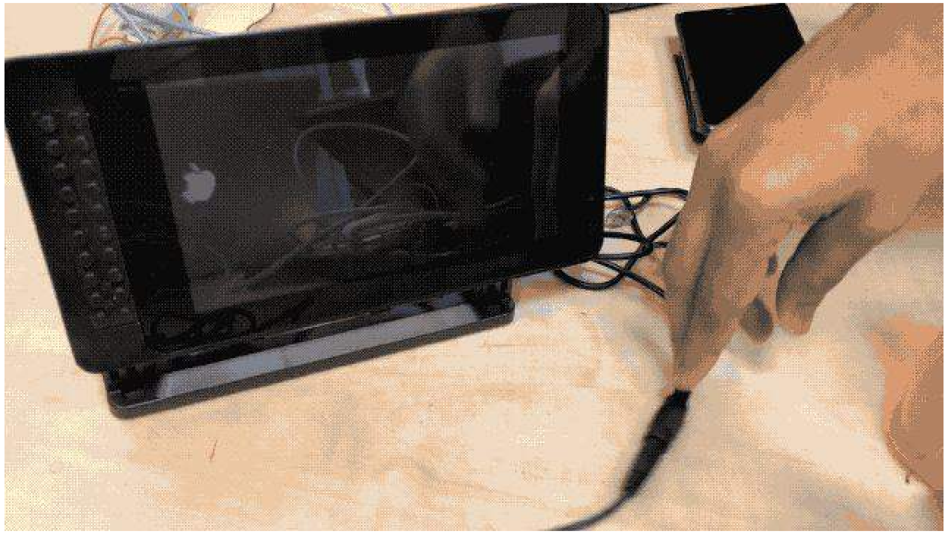
<u>Prototyping (Thursday)</u>



We have received the Healthy Pi v3 from ProtoCentral and started testing with it. The Raspberry Pi is a Linux-based platform and is able to be programmed. The Healthy Pi HAT provides 3 vitals from the sensors coming with it - the Oxygen level, ECG, and temperature. Currently the program will only run on startup and we haven't found the actual programm together with the code that was preinstalled on the device so we might need to reinstall the software.

Next, we will try to customise the screen to display the similar info as the real monitor in the ICU and try to connect sensors to it to change the display behaviour according to what sensors detect.

Once the ICU patient monitor data is received from drager we'll also try to simulate this on the raspberry. This could make the display more believable. If possible it would also be interesting to calibrate the device to an actual monitor to ensure proper readings from the prototype. This would, again, add to the final product credibility.



Next week

- Email Teus to receive Drager/patient information
- PE presentation deadline 27-3
- AEF report deadline 28-3
- ADE deadline 30-3

End of the week briefing 7, 29.03.2018

This week we finished deadlines for two of the expert areas, **Product Experience (PE)** ar **Advanced Ergonomic Feasibility (AEF)**. For Product Experience we finished the presen and presented it to the Product Experience Experts and some of the other students. The Ergonomics report has been finished and submitted, next week we will discuss the report (the AEF presentation.

PE

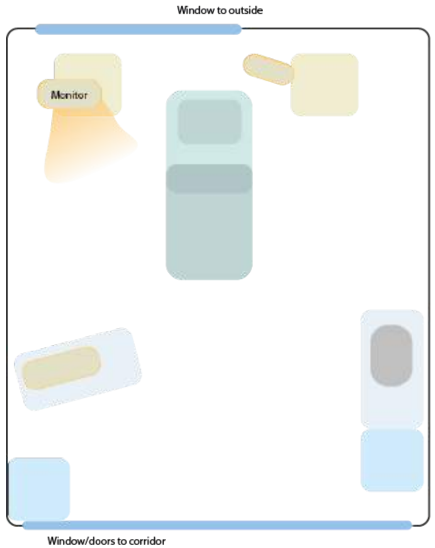
After the Product Experience presentation Elif gave us some tips to improve or experience which we will incorporate and improve. We will focus on one user - clinicians and make it f his/her perspective.

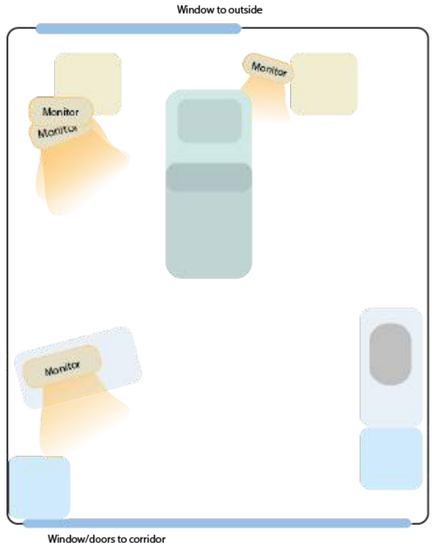
CONTEXTMAPPING

MOODBOARD

AEF

We compared the light measurements from ICU with our sleeping conditions and tried to validate with literature. The light of the ICU, in general, should be reduced to a maximum illuminance of 70 lux, as the guidelines suggest and lower whenever possible. Within the current ICU, this is possible to achieve when the lights are turned off. The monitor itself should be designed so that it turns off when not in use, and thus not disrupt the patients' sleep, or at least be dimmed to match the brightness of the environment, which would also be optimal for the nurses. The blue light waves should be suppressed and replaced by warm light during the night to keep the body from perceiving it as day.





For the presentation for AEF next week, we will each individually research and read a report linked to our project. We will make a short summary with the most important points which we will present to each other.

This week we worked in two teams, to divide the workload and work more efficient on the different subject. This proved to be working, especially because we still involved everyone in decision making and helped wherever needed.

Next week

- Prototyping
    - Sensor Research & Brainstorm
    - Understanding the code
- AEF presentation (Discussion) (4-4)
- PE improvements
- SDE start report (deadline 9-4)

End of the week briefing 8, *06.04.2018*

This week we have carried out a exploration on sensors, which is of significant importance of this project. Based on the exploration, we have come up with several initial ideas. Besides this, we thought about both the biggest technical and organisational difficulties during the Coach meeting with Maurits, which helped us have a better grasp and focus on this project. We agreed that designing the sensing system (selection, combination of the sensors and safety issues) and developing it (coding) are the biggest obstacles and we will put more energy into it. In addition, we also got feedback of our ergonomics report on lighting issues inside the ICU and it was really good.

AEF (Tuesday)
During the meeting of ergonomic expert with Peter Vink;
we discussed our report, with which he was pleased;
each of us held a short presentation about different reports we read that were relevant for our project and the outcomes we could use:

- A set of PIR sensors and Fresnel lenses located at a height of 0.8 m from ground presents the best performance for path-dependent human identification.
- In the cases of a pair of wall-mounted modules facing each other, we could achieve almost or more than 85% recognition accuracy for classifying walking directions, distances and speeds using just a single PIR in each module.
- Human tracking in an area is possible using a radial sensor module with eight PIR detectors with Fresnel lens array arranged around a circle.
- *Medical equipment should be intuitive to work with and not require nurses to learn how the monitor works or memorize how and which tasks to do. The clues should be perceptual.*
- *The current monitors can still easily be optimized using relatively small changes in the interface, so no extra manufacturing costs.*
- A clear and obvious interface helps nurses to focus on task at hand instead of what the monitor is trying to convey.
- The acoustics of the ward interior or the way in which the alarm sounds can create a “busy area” of alarms and cause more fatigue.
- There is no general way to handle visitors since they all behave differently.
- Clinicians are not very accurate in predicting family perceptions, needs, or needs satisfaction.
- Need of function to prioritise, turn off or silence the less important monitoring equipment.
- Intuitive interface to reduce the learning time and to speed up settings adjustment.
- Possibility of monitor movement to provide physical space when performing basic nursing care but still being able to easily read the data.
- Stable connection of cables to the patient and medical devices to support during patient position changes, turns and changing sheets.
- Vital signs reading tops in high risk of error tasks
- We need to use actual patient monitoring data in our prototyping
- Our design should help reduce the nurse’s response time of reading the vital signs to increase their Cognitive Work Ability.

Sensor Research (Tuesday)
We discussed several sensors for the people recognition system and evaluated them on multiple criteria. These criteria are (in order of importance):

- Differentiate(how well does it achieve our target goal) **[10]**
- Equipment safety(does it interfere with existing equipment)**[9]**
- Prone to error(can the measurements be wrong)**[8]**
- Intrusion (least intrusive way to intervene in the activity of the staff)
  - Doing(do users have to perform an activity to trigger the sensor) **[7]**
  - Carrying(do users have carry additional things to trigger the sensor)**[6]**
- Implementation(Can we use it in all different kind of environments)**[5]**
- Development(how easily can we build it)**[4]**
- Privacy issues **[3]**
- Installation (is it easy to install)**[2]**
- Pricing (how costly is full implementation of the whole system)**[1]**

By using this list we could obtain the three most promising sensors to develop some initial ideas for their implementation. These three sensors are:
- RFID
- IR camera
- Camera(object recognition)

Although these three sensors are the most promising in terms of the previous defined aspects, the other sensors might also be of use when combined with each other.

Sensor implementations

<u>Active RFID</u>
RFID could be used to identify people upon entering a room by the use of a tag and reader. Every person carries a tag along with them and the reader detects when a tag enters into a particular zone and identifies the person. There are two types of tags, Active and passive. Passive tag is just a inductive circuit that receives electromagnetic energy from the reader and sends back the reader. But it requires the reader to send large amount of EM energy to the tag for it to be able to send it back to the reader. But this eventually affects the hospital equipment. Active tag is powered by a battery which needs less energy from the reader station, but requires the clinicians to carry a rechargeable device all the time.

<u>IR camera</u>

Infrared reflective stamp

IR camera is a device that forms an image using infrared radiation, similar to a common camera that forms an image using visible light. Instead of the 400–700 nanometre range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm (14 μm). With these properties we could use the IR camera to detect tags made from IR reflective materials without it being visible for people. The IR camera would first detect people based on their thermal image and then look for the IR reflective tag to identify them. This tag could be created simply by working with IR reflective paint and putting it directly on the clinicians robe. Using IR would not require any visible stamp otherwise used by normal cameras.

<u>Camera(object recognition)</u>

The camera can be used for object recognition in various ways. There are already trained models on recognising people in a image or video, so this could be used as a initial detection method whereafter a distinction is made between clinicians and visitors based on color, shapes, etc.

Another option would be to train a model from the ground up using a big image database of visitors and clinicians(preferably from video footage in multiple hospital environments). When done correctly the model could differentiate between clinicians and visitors in any room and also improve its accuracy over time. This would however require lots of time in order to create the database.

Another use of the camera would rely on multi-camera multi-object tracking. This would allow the system to track each person within the ICU and determine their location within the entire ICU. Upon entering the ICU the setup would tag a person with their corresponding ID, by means of facial recognition, card readers, or any other identification method. All untagged people would be considered visitors. After registration the multi-camera setup would use feature detection methods to follow each person on different cameras at the same time.

SDE

The experts for sustainability discussed our prime objective and stakeholder analysis. Minor changes have to be made, more about the formulation of the part, but the overall information and analysis were good. Next week we start with some fact finding.

Next week

- Appointment with Gerd, the guy from IoT, on Tuesday (12:00)
- SDE Fact finding Tuesday afternoon
- *Mostly:* Draft (monday) and final mid-term report

If we had extra time

- *Study sensors from existing products such as train station gates and people counters*
- *Further analyzing existing products*
- *Move plants to bigger pots*

Growing Garden

After it seemed like the Sunflower was dying on us, a new one grow and has grown so tall it needs to be moved to a bigger pot.

Some carrots also started to grow and within the week grown to a size, ready to be moved.

At the end of this week one of the tomato plants carefully showed its face. The little guy still has some growing to be done before it can be moved.

Next week we should bring some pots and dirt to move the plants to a new and bigger home.

End of the week briefing 11, *26.04.2018*

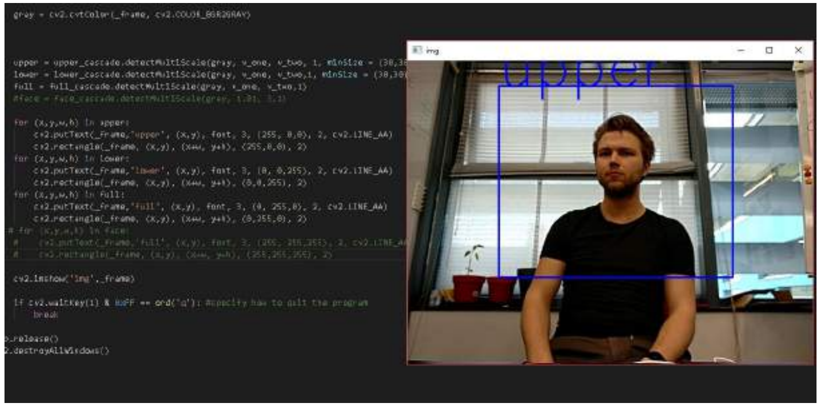
The first week of the second quarter. On monday we discussed within the group about the presentation, it’s feedback and what the plan is going forward. We started a new subcourse, smart system technology, which seems promossing during our prototyping. We made a rough division within the group on who will work on what, David works on the Identicam prototyping while Nitin and Yuxiang work on the infrared camera. Shaoyun is working on the user scenario, the workings of the sensor. Anna has made a start on the embodiment design of the final concept of monitor and sensor whilst Doris is busy with creating a convincing and clear context, which is useful to make everyone aware of the context and each user during the end presentation.
Furthermore, members of our group attended the graduation presentation of Koen and the ADE and PE feedback meeting.

PE expert meeting
On 26.04 we had a meeting with Haian about our progress and implementation plan. The feedback which we have received informed us about our performance during first PE presentation. Our information and content was good but poorly presented. It resulted in a grade 5,5. Since that we improved the visuals and prepared a clear experience maps. During second presentation the progress was visible but we should include more information about the context to improve the understanding of a problem among the audience. Our implementation plan is sufficient and was approved. Our current grade which provides us an awareness of our progress in 8,5.

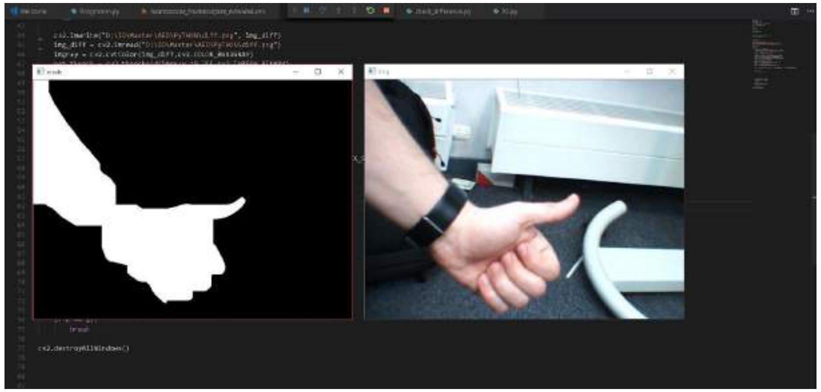
ADE expert meeting
On 25.04 we had a meeting with Zoltan about the implementation plan. We proposed to use simulink to model the virtual ICU environment and simulate the cameras. This would help in understanding the performance of the PinchGo concept which uses multiple cameras to track the clinicians in an ICU and compare it with IdentiCam concept. On the other hand, the Zoltan also suggests us to explore the options of modelling IR cameras, Pyro Infrared and RFID sensors which are used in other concepts of UltiForm, IR QR and RFIDea. But still the evaluation criteria needs to be defined clearly that what type of parameter is going to be used to compare the concepts and evaluate. So for the upcoming week Zoltan suggested us to model the environment and try to place the sensors, and plan for a follow-up meeting.

Concept prototyping
This week we discussed which concepts to further develop. Since the five concepts use basically 3 different sensors(infrared, cameras and rfid). We decided to divide the concepts in 3 parts with their corresponding sensors. Some team members started to further develop these prototypes in order to make them function.

We’ve looked at the OpenCV haarcascades to identify body parts(as seen in the image). However this does not yet result in accurate readings with far to many false positive for any reliable system.

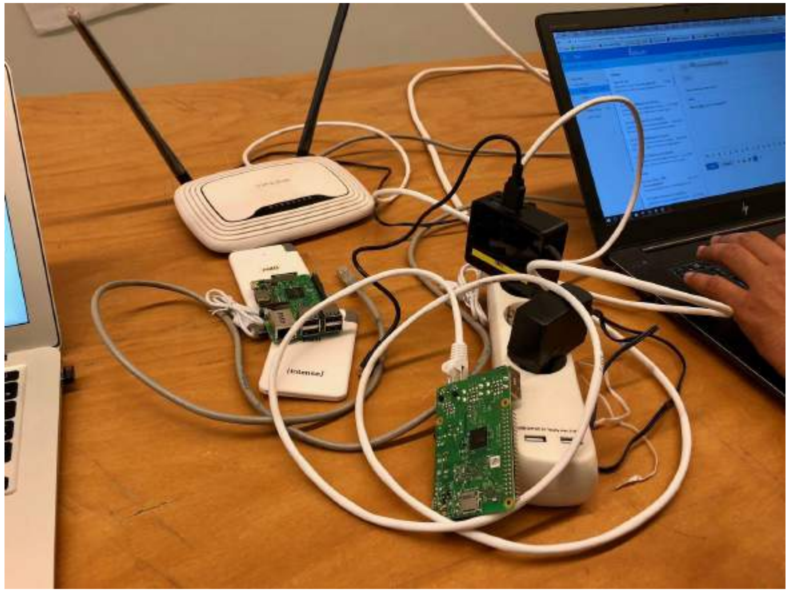


Aside from this we started writing code to detect the difference in an image. This shall be further developed to accurately detect passing people through any entrance. For now it only detects change and highlights this(see image). The change in the images are thresholded in such a way that objects that are cut off for some reason(the watch in this case) are stitched together properly(and thus seen as one object).



This camera sensing technique is derived from the Density people counter product. This device uses IR sensors and projections just like the Xbox kinect to get a depth map. However, as we didn't have these sensors we started trying out a different way to achieve somewhat of the same result.

We also started prototyping with Raspberry Pi, on which we can test the code using a video camera or a Kinect sensor (we will get it next Tuesday) to count people.



We bought:

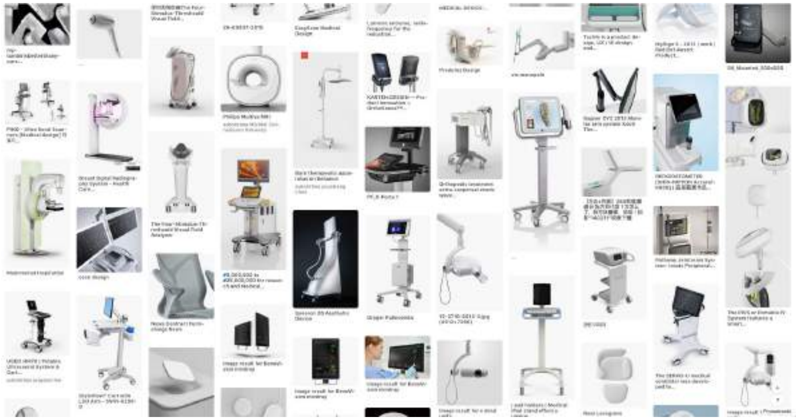
Item	Date	Price	Quantity
NoIR Camera for Raspberry Pi	25/04	€29.95	1
LED for NoIR	25/04	€16.95	1
Kingston microSD 16GB with adaptor	26/04	€10.5	1

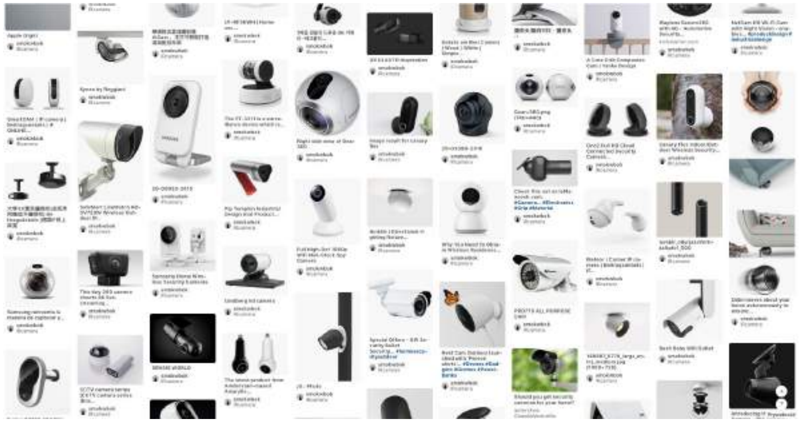
Context
We started on a storyboard for a short movie that shows different users in the current ICU environment. Combining it with narration of the users feelings will create a clear understanding of the current situation and why it needs to be changed. This situation will, during the final presentation be compared to the future situation. The differences will become clear even so the importance of these differences. In the future scenario movie our part within the bigger project will be made clear and it's job and position in reference to the whole project will become more clear from the beginning of the presentation.
At the end of the presentation we could reference back to the future scenario and show our product works and fits into this environment, using a video or animation.

A draft storyboard is made to indicate the current scenario inside of ICU which will be further implemented. The customer map after applying ULTIMO system will also be finished next week.

PE

We are still researching the aesthetics of the monitor but with bigger focus on the details and the camera,sensors and RFID appearance guidelines.





The Garden

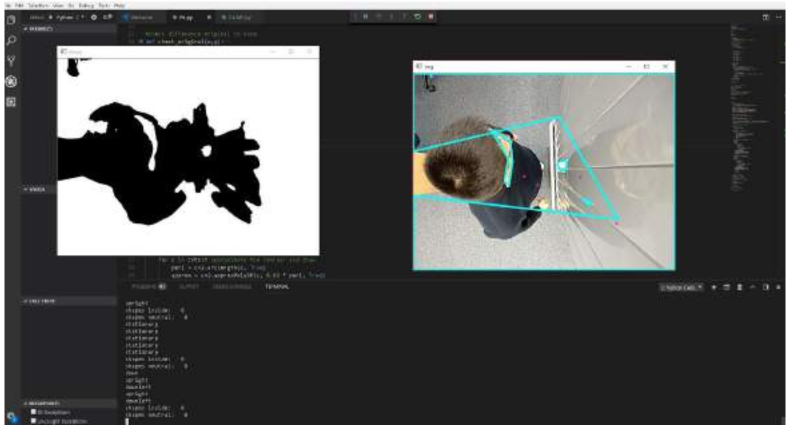
It has been some weeks and our garden is growing steadily. Although we do not have any hopes for cucumbers anymore, the rest is growing steadily. The sunflower is rising to the sun. We also have some plants of what we do not exactly know what they are, but they are growing, so we are happy.



End of the week briefing 12, *05.05.2018*

Prototyping

IdentiCam:

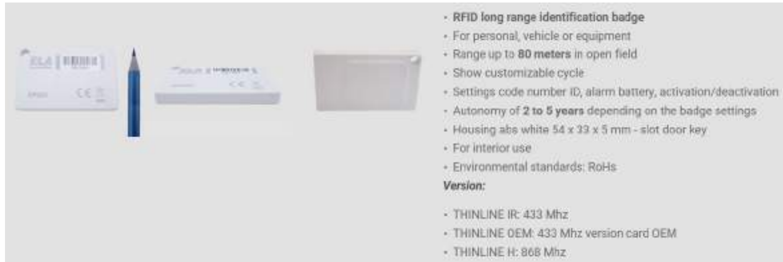


The camera detection system is nearing its endphase. The main functions are in place but have to be calibrated to ensure proper workings. The system works by detecting the change of an image, calculate the center of the shapes found, registering where this shape is going and evaluating whether the person entered the room. The main problem of the system now is proper/ consistent camera exposure, correct difference detection, optimizing framerate and optimizing frame bounds for counting accuracy. Further steps in the developments of the system involve quick system calibration for different rooms, separating the different shapes and evaluating whether they are clinician or visitor.

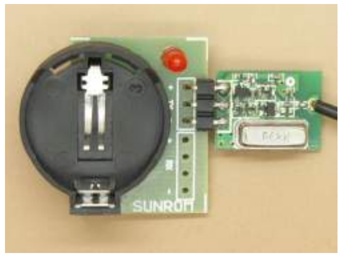
Optimizing the current system can be a valuable asset in combined systems using counters and identification tags. Further development might make this a standalone system capable of counting and identifying.

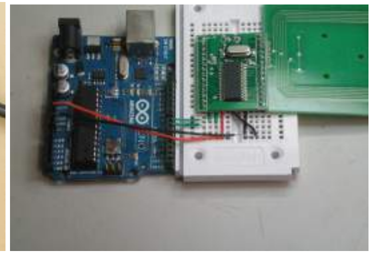
RFIDea:

We explored the possibilities of prototyping the concept to detect the people entering in patient room. Passive RFID is widely being used in the market for this purpose, but as we know we cannot deploy this system in hospital as it requires the clinicians to scan the tag close to the reader upto 10 cm from the reader. On the other hand, there are plenty of commercial systems available for active RFID as well. We spoke two companies called Cisper Electronics BV and ELA Innovation S.A explaining our requirement for the current application. They suggested few UHF readers that detect the RFID tags within the range of 5 to 50 meters. We also requested them to suggest a reader that can emit the signals in a particular direction in order to avoid interference with other medical equipment and awaiting their suggestion.

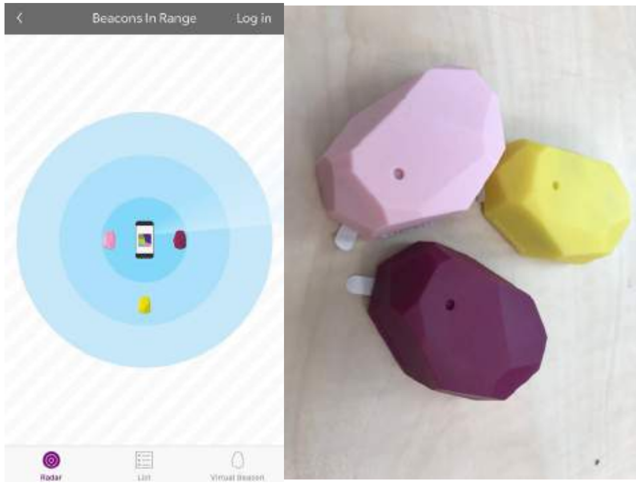


But we also see the challenge in using these commercial products to communicate with our raspberry Healthy Pi as they have different protocols again. We spoke to IoT experts and came to conclusion that commercial systems would be good idea if we are going to develop the final product that is going to be manufactured and deployed into market. But for the current assignment, as we are trying to prototype and evaluate the concept, it is advisable to use developer kits like tags that are compatible with arduino or raspberry pi. But these tags work with a frequency of 125KHz which can only detect the tags from a distance of 10 cm. There are another range of RF transmitter and receivers at 433MHz. These tags are active and uses a battery to communicate with the reader. These tags can be detected from a distance of 24 meters. So it is possible to use these tags to prototype and detect the person and distance from the patient room. We currently need to source this active module as it in not available in netherlands so far in the research, once we have the tags sources, the concept can be tested by placing the active tag on the people's clothing and identifying with through arduino based reader.

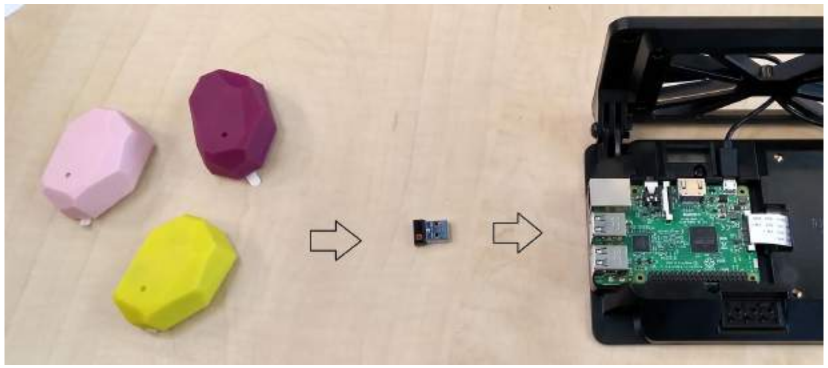




Beacons:
We began to explore the possibility of prototyping Beacons sensor. We borrowed the estimote sensor from faculty which contains 3 devices that are able to send and sense beacons signal and might be possible to be used for location tracking. Using ibeacon technology those devices can be found by iphone and senses the proximity.



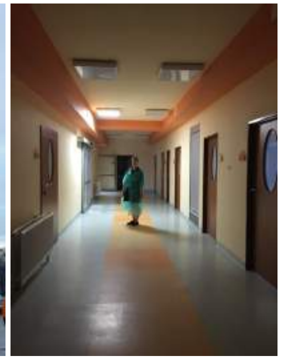
The next step is to set up the devices to detect moving objects and make it talk with raspberry pi. The beacons can be detected with a bluetooth doble attached to raspberry. Raspberry pi si then enabled to scan the surroundings every second through the dongle to see the beacons. Later the code can be further implemented to read the distance of a particular beacon from the reader. This can be used to identify few moments before the clinician actually enters the patient room so that alarms can start up slowly.



Kinect
We received the Kinect sensor on Thursday, which may help us better calculate the number of people in the patient box. But it comes without a power supply and we will buy one soon and start working with it. If it works properly, we will compare the performance of this technology with the one used in IdentiCam, which is solely based on image process.

Context visit in Poland (Anna)
#This is sensitive content, please don't post it online.#

Edward Szczeklika Specialistic Hospital in Tarnów, Poland

Taking advantage of my trip to home - Tarnów in Poland I visited one of the hospitals in the city. Founded in 1835 Edward Szczeklika Specialistic Hospital is one out of two hospital in city with one hundred and twenty thousand inhabitants. Thanks to the affability of the personal. I visited ICU in Anaesthesiology and Cardiology department and Emergency

Room. I talked with an ICU doctor, nurse and doctor from Emergency Room. They were a semi formal interviews.

ICU in Anaesthesiology Department, interview with a anaesthesiologist dr. Beata Barnaś

The ICU has a centralised nurse station with multiple patients in the same room. There is 7 beds, one doctor and 4 nurses per shift. Nurses have two shifts per day which means that they work for 12 hours. 5 patients beds are in a main room and two others are single ones for a patients who require isolation. All patients are unconscious. During the day light is natural and dim by blinds in windows. At night light is turned on over the central station and temporary over patient's beds who requires care at that moment.

The monitors used by the ICU were made by a polish brand EMTEL and are combined with a NEC display. They are the oldest equipment in the department and the order for a new ones is in place at the hospital administration.

The monitor is placed on the mobile arm together with other equipments. It is located high to enable the nurses to see the display clearly from a distance. The heavy arm and great hight result in a need to use additional object (ruler) to operate it. It has a relatively small touch display with separate measuring module. Modules were evaluated as good solution because they can decide which they want to use and when something is broken they can exchange it fast and easily. Alarms volume can be adjusted and is set on the lowest limit. The only loud alarm is the respirator one. It is done intentionally because it is the most important alarm, which they always want to hear. The brightness of the monitor doesn't change. All patient data is also displayed on one monitor in a centralised nurse station. That monitor also indicates alarms by a sound.

Dr. Beata Barnaś multiple times express her disappointment about the monitors they have. They were bought without the consulting the clinicians and are not changed since 10 years. She works in an office next to the ICU. Whenever the serious alarm occurs one of the nurses comes to her or call her by a phone. There used to be pagers but now they use their private mobile phones.

Asked about visitors she said that it is always a huge shock for them to see their family members unconscious and in critical condition. They are afraid to touch a patient even to hold a hand because they are afraid that they will accidentally disconnect any sensor. Very often they focus on the monitor and the displayed values. They often remember the values from previous days and compare them with current. They are trying to estimate the patient status and spot the progress. Sometimes they check on the internet the values and their meaning for a patient health. She was excited about the idea not to show the technical data to the family and suggested to express patient condition by a simple image.

ICU in Cardiology Department, interview with a nurse

The ICU has a centralised nurse station with multiple patients in the same room. There are 4 beds and 1 nurse per shift. Nurses have two shifts per day what means that they work for 12 hours. All patients are conscious. The light is turn on during a day.

The monitors used currently by the ICU are a bit newer than the one in the Anaesthesiology Department but made by the same brand EMTEL with a NEC display. Alarms volume can be adjusted and is set on the lowest limit. All patient data is also displayed on one monitor in a centralised nurse station. That monitor also indicates alarms by a sound. The brightness of the monitors can be changed manually. The brightness is changed remotely from the centralised nurse station 4 times a day to make a change gradual.

The nurse said that she doesn't mind alarms anymore but at the beginning of her work, ten years ago, it was a big problem for her. She mentions that sometimes she still hears alarms in her head after work. Patients at the beginning are very scared about "whole monitoring thing" but usually also get used to alarms after a longer time. Patients cannot see their monitors but can hear alarms. It makes them nervous when they hear them for a longer time and don't understand what is happening. Very often they ask nurse to come and check altho it is a false alarm. She said that there's one lady now who cannot completely sleep due to the alarms and complains a lot.

Emergency Room, interview with a doctor

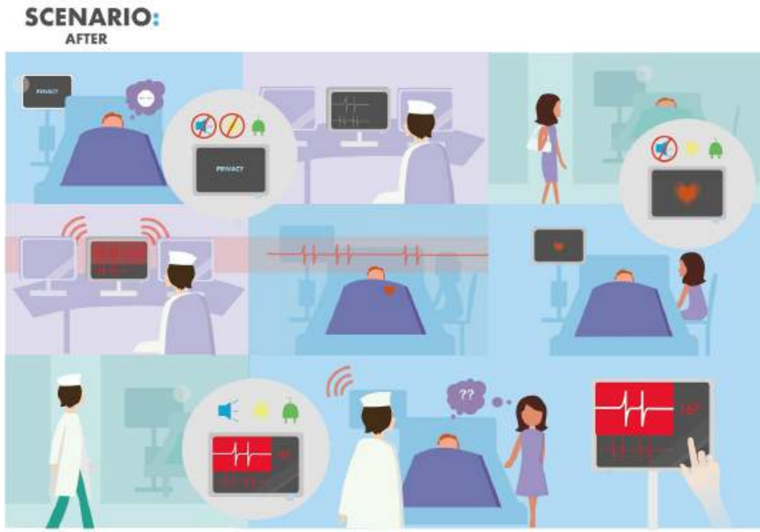
In the emergency room there are two types of monitor. One mounted on the stand with trolley. It is new but the doctor said that they prefer the older ones. This one has a few nice functions and accurate sensors but the alarms are annoying. Sometimes the false alarm occur the whole time for one measurement. It is impossible to turn it off completely even though there is no need to control that function. Even when the volume is low it is still very loud high pitched constant sound. It can be operated only by buttons. Second monitor is a portable monitor combine with a defibrillator. It is used for a patient transport because they always want to have also defibrillator in case of the emergency. He also mentions that he always changes the limits for values when they are wrong because they will get crazy hearing all of them.

Conclusion:

- Many users' behaviours are the same regardless social and cultural differences.
- Visitors are often focused on the monitor and pay attention to even small changes in values. Data presented on the monitor makes them anxious.
- Patients cannot see their monitors but can hear alarms. It makes them nervous when they hear them and don't understand what is happening.
- Alarms are a disruption to sleep for some patients. They complain about it to nurses.
- Nurses prefer to set alarms loudness as low as possible.
- Stationary monitor and portable one should be separate devices. Stationary one should have separate measuring modules and the portable one should be combine with a defibrillator.

Context

This week we continued with the storyboard for movie and for context mapping. In the scenario map, 3 background colors stand for the 3 contexts, blue for patient room purple for nurse station and green for the hallway.



Current storyboard video is placed inside the End of the week briefing drive folder.
This is the nurses point of view and hereafter there comes a part where she helps another nurse when a alarm sounds from her pager which she sees and sees it's not urgent so she continues helping other nurse, but then there is an important alarm and they rush to the patient's room, the visitors have to leave, and they handle the situation. After that rest returns to the ICU and shortly after the visitor comes do the door again because the patient has woken up. Then the nurse goes to patient looking at him (checking eyes) and explaining he is in ICU and taken care of.
Maybe thereafter there could be a segment of the night where some alarms sound and sometimes nurse has to walk in and take care of patient.
I would then like to make the same scenario but from the visitors point of view, and one of the patients when he wakes up. The night segment could there be most useful, but the video would then maybe become too long… That's why the storyboard is created so that the story and scene order then can be discussed with the group before filming. So that there are no unnecessary parts filmed or parts missing.

SDE

For SDE this week we finished the fact finding part of the course. We finished the material, energy and environment facts of last time and research fact about the legislation, societal and economical aspects.

We found a lot of information and facts that supported our earlier guesses.

However, some parts were hard make real facts about, like the materials we use in the system since the whole system is not yet determined. By making assumptions, and state that those are assumptions, we could finish the workshop and are awaiting the feedback on that.

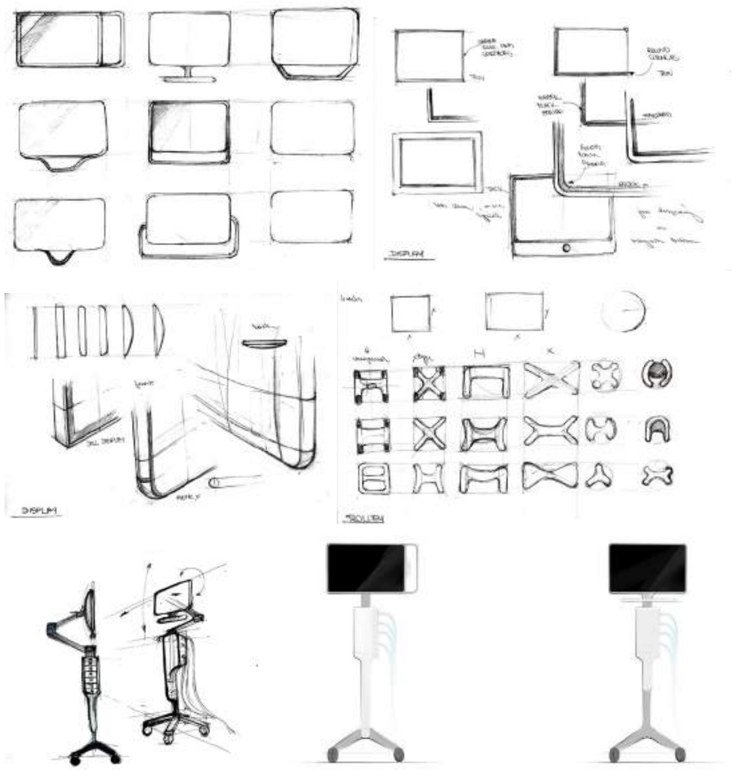
Greetings from Gaja from Poland

Cherry tomato coming soon!

End of the week briefing 14, *18.05.2018*

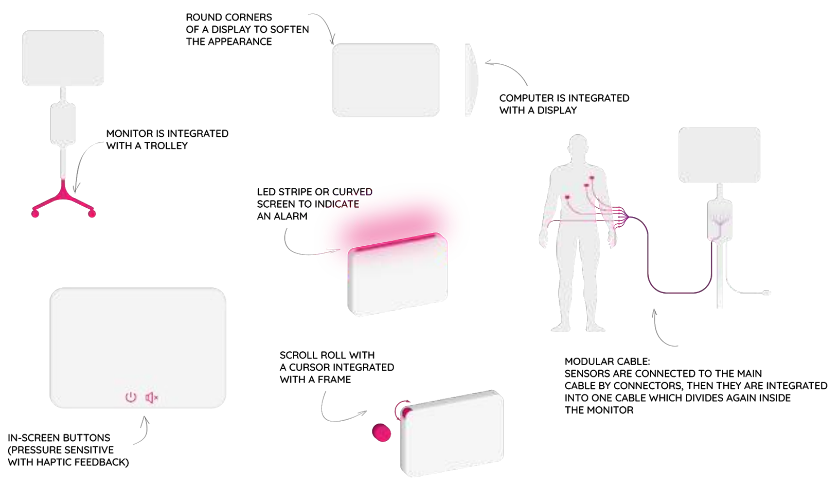
Embodiment design:

As we were prototyping, we also started exploring the exterior of the monitor because we want this innovative patient monitor to be aesthetically pleasing as well. We need to let the user feel that this monitor is modern, smart and new. We try to make a big leap in the patient monitor design. We did a brainstorming on that and here are some of the pictures.



Brainstorming:

As the results of the brainstorming we chose some main characteristic of the Ultimo monitor:



Sensor development:

As we discussed in the previous briefing, we evaluated the usability of RFID and Beacons. Firstly, commercial devices of RFID are difficult to reverse engineer for prototyping purpose. So when we explore the developer versions of RFID sensor, they work at 433MHz which seems not suitable for usage in an ICU. So we focused on beacons that work with Bluetooth Low Energy technology. We used estimote beacons to connect to a bluetooth scanner. There were two possibilities either scan through JSON library on raspberry pi or scan through android application. These scanners receive the ‘rssi’ value(signal strength) from a specific beacon and calculate the distance of the beacon from scanner. But this rssi value could be fluctuating continuously due to environmental interference. Android applications were optimised to normalise this fluctuation. So we installed android 7.1 on raspberry pi so that we will be able to run the application from raspberry and trigger the screen.

Similarly, the camera placed over the entrance was able to identify a human walking inside or walking outside of the patient room though OpenCV. Also we are currently prototyping stereo vision. This uses two cameras placed above the monitor and uses triangulation method to calculate the distance of a person from monitor.

On the other hand, we were successfully be able to read the data from patient sensor to plot in the form of graph and present the status using python. That means, when patient sensors are connected healthy pi board, we can present the patient vital on screen and trigger between patient, visitor and clinician mode. But this can happen only when the estimote application and the camera tell the python that they have detected a person entering into the patient room and it is a clinician.

The major challenge at this

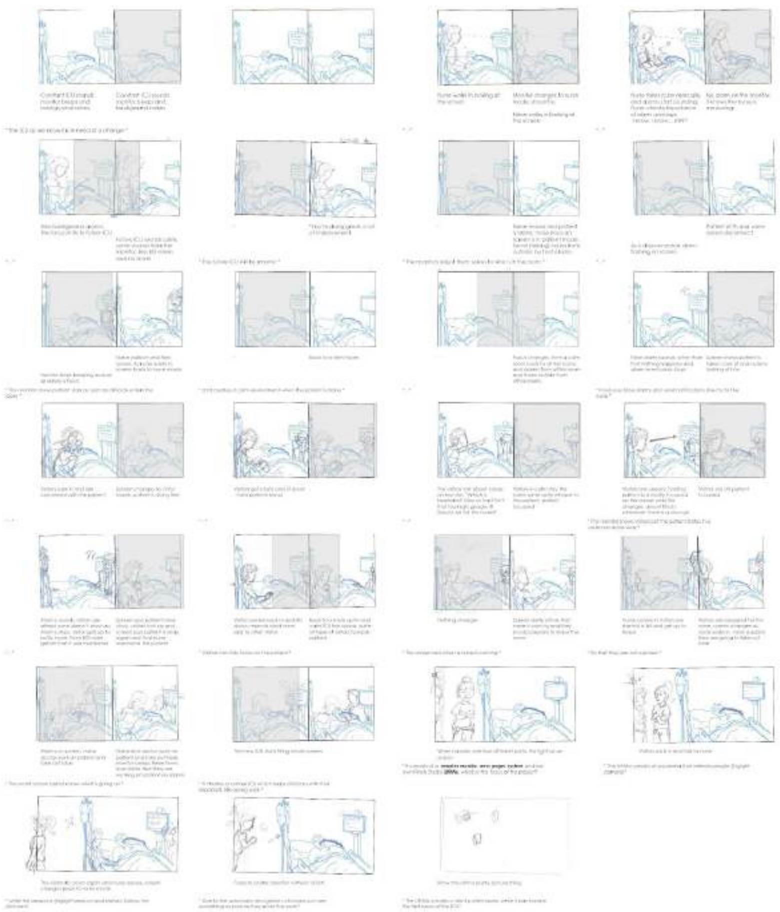
phase is to make all the these three individual system communicate together. For this it is important that all the three run on a single OS on a specific hardware. We are currently involved in figuring out how to bring estimote calculation into python, which eventually helps in triggering the display as per plan.

PE Measurement plan:

As the research area we chose two cells from the graph: meaning and emotions in micro scale. We decided to conduct a quantitative research to answer the question: How can the display inform and calm visitors at the same time?

We decided to present 8 displays, including current display and new design of different contexts, to 15 participants. There would be both quantitative and qualitative research conducted on micro and macro level.

Context movie:



During a discussion with the coach about the current context movie, we came to the conclusion that it has to be altered. A new storyboard has been developed where a scenario is shown twice, once in the current ICU setting and once in the future silent ICU. So one half is the current ICU and the other half is the silent ICU. By switching the focus between the two ICU's during the movie, the difference between the two ICUs and the impact of the new ICU is made apparent. (Switching focus in making the colors faded and turn of the sound of the ICU which is not in focus).

To prevent the video to be too chaotic, I chose a single standpoint. So no cuts to different views.

At the end of the movie, the whole screen becomes the new ICU and it zooms out where we show what things are tackled and which part of the future ICU we try to tackle with our project.

Next:

Next week monday is another holiday, the last one until summer vacation.

On Tuesday we have another SDE workshop, where we will focus on Synthesis.

On Thursday we have a meeting with Agnes, were we will talk about out PE measurement plan.

On friday Anna and Doris will visit erasmus in the morning to observe the workflow in the ICU. We have several points on which we want to focus on for our project.

Appendix / PE measurement Plan

Method

To test the expected result stated in the introduction, a pilot study was done by recruiting 2 random participants. Based on the result the following method was rewritten.

Participants

A population of 15 people, consisting of males and females, was gathered to participate in the study, in a range from 20 to 27 years old. They were recruited at Delft University of Technology.

Stimuli

To explain the context to the participants a short piece of information was read out loud and the slideshow of a pictures from the hospital was shown. Thereafter, participants were confronted with two examples of the display content of the current ICU monitor and 6 proposals of the new ones. To evaluate them two methods were used. After gathering some personal data (age, sex) the displays were shown to the participants. After each of the examples an individual interview was conducted based on a prepared list of open questions. This method was chosen not to suggest participant any exemplar answers. Afterwards, the monitor content was displayed second time. Following every example, participants were asked to fill in a questionnaire made with the use of likert scale. It is a simple and fast method which provides with the gradual results for the evaluated characteristics.

Apparatus

Apparatus included a TV displaying the content of ICU monitor in the form of pictures, an A4 sheet of paper, a ballpoint pen (to take notes) and a questionnaire sheet.

Procedure

Study took place at the Care Lab which is a facility of the Delft University of Technology. The participants took part individually in a study for 20 minutes. First, the participant was asked if the gained knowledge could be used for further research. Then the moderator gave an introduction and explained what the research is for and what the research will be like. After this, the context presentation was shown to the participant. At the same time, the moderator introduced a scenario of the imaginary situation in an ICU into which the participant should empathize. It was divided into two parts: a stable state and an emergency situation. For each group 4 pictures was shown which are: the original display of drager monitor, illustration of static icons, illustration of static icons and text and illustration of dynamic icons and text. The order of the pictures within each display group will was varied. After each of the ICU monitor content the participant was interviewed based on the written instruction. When the first cycle was finished the participant was provided with paper and a questionnaire. The examples of the content were displayed again. Following each of them the participant was asked to fill in the questionnaire. In order to obtain trustworthy results, half of the participants started with the stable state examples and the other half started with the emergency situation.

Measures

All answers on questions were noted in a spreadsheet. Before starting, general data of the participant was noted. This included gender, age, if they agreed that pictures were made during the exercise and whether they had any experience with ICU before. Results gained by means of a interview and questionnaire (in English) gave both qualitative (open question) and quantitative (rating from scale) data. To process the qualitative results, the list of the words was made for every question. Number of them and recurrence were calculated. The outcomes was presented in a graphs and bundled in word clouds for each display and in one overall world cloud. To process the quantitative results, the K line score graph was made and the average scores for each monitor content was indicated.

Appendix / Studied materials

8 displays content presented into two groups:
Stable:

1. Current display
2. New display with static icons/illustrations
3. New display with static icons/illustrations and text
4. New display with dynamic icons/illustrations and text (animation)

Emergency:

5. Current display
6. New display with static icons/illustrations
7. New display with static icons/illustrations and text
8. New display with dynamic icons/illustrations and text (animation)

Appendix / Interview questions

Participants will be ask to answer the question in one word.
How does it look?
How does it make you feel?

Appendix / Questionnaire

List of the sentences for the likert scale:
I know what is the patient status/How does the patient feel.
It is easy to understand the illustrations.
I can see the patient is being monitored.
I feel nervous/ intense seeing the display.

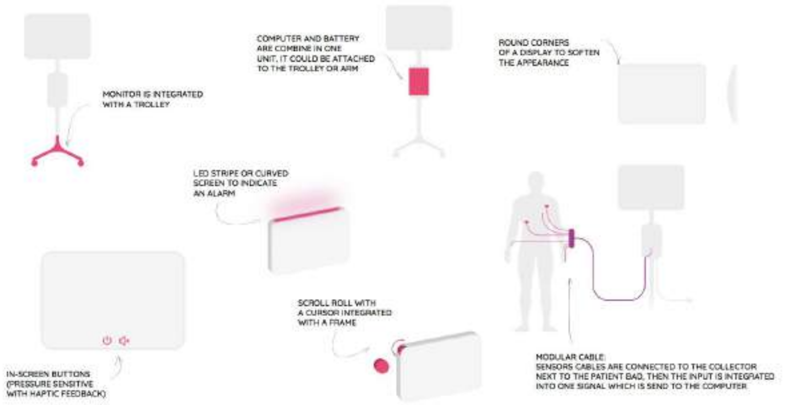
Appendix / Form of consent

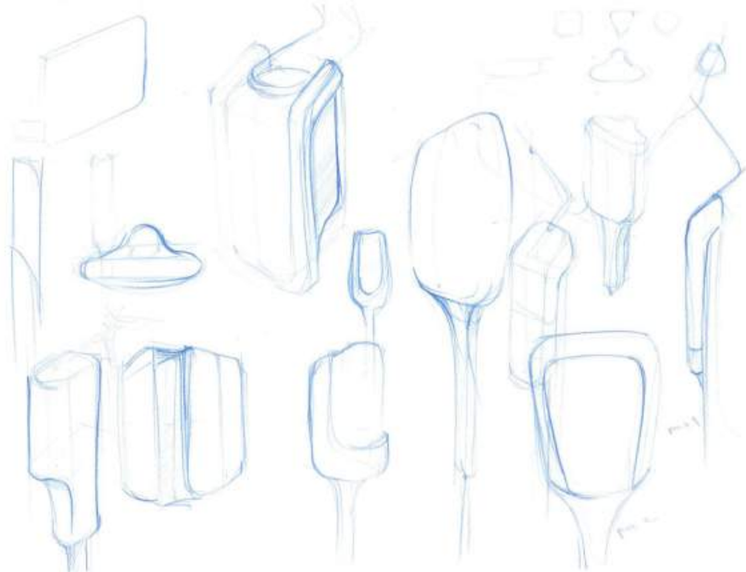
Verbal consent from participants was gained for:
The use of results from the interview for this study only
The use of results from the questionnaire for this study only
Taking pictures during the study

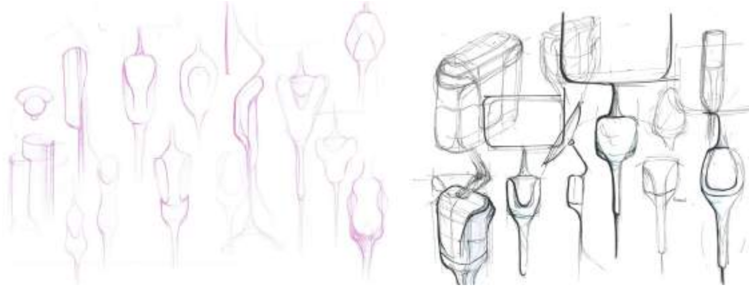
End of the week briefing 15, *25.05.2018*

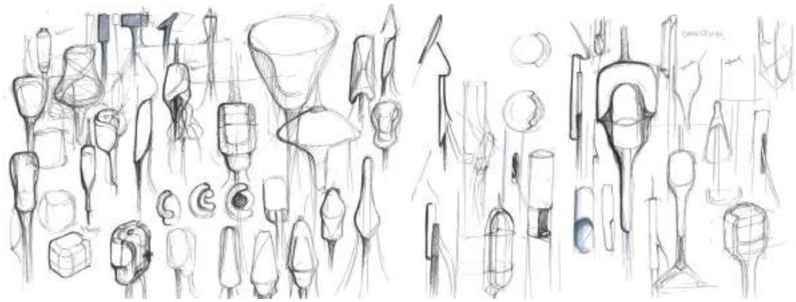
Embodiment Design

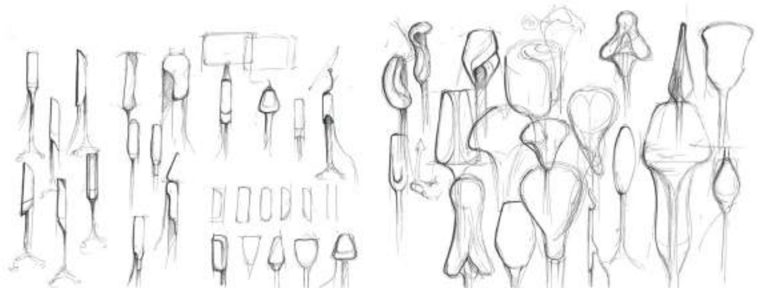
This week we had more sketches of the monitor design and updated the requirements. The computer and battery are combined in one unit which would be attached to the trolley or arm, or even on the back of the wheelchair. We would also have a modular cable: the sensor cables are connected to the collector next to the patient bed, then the input is integrated into the signal which is sent to the computer. Therefore the monitor would have three main parts connected with cables:
Sensors - multiple cables - **collector** - single cable - **computer combined with battery** - single cable - **Display 1**(attached to different stands 20”-22”) - **Display 2** (smaller one used for patient transportation)











Prototyping

With the help of Elif we bought estimotes. They will be used to identify the clinicians when they enter the room.

On Friday Doris's boyfriend, Lars, who studies computer science came to the studio and kindly offered help on our programming problem. He looked at a some part of the code which enabled us to actually display data from the healthypi realtime. There is still a problem with the frame rate which has to be resolved but this is a minor issue. Next up is displaying multiple graphs of all the sensors on the screen and being able to input 'modes' that initiate a screen change.

For the detection part a final decision is made on using a single camera at the entrance to detect shapes by using a background subtraction method which takes multiple frames into account. This way we are able update the background when something is moved inside the cameras line of sight.

Context movie

This week we discussed about the context movie storyboard and had some primary ideas about the set up of final presentation. We decided to show context video of the current and future ICU at the beginning and during the presentation, and to show the 3 minutes video including further explanation of our project (mandatory one) at the end of our presentation. We made a separate file of the presentation set up and are looking forward to get feedback of it. Depends on the feedback we may adjust the content of the movie or split it into parts.

PE Measurement Plan

At Tuesday we had a meeting with Agnes and got the feedback of our measurement plan. Instead of asking qualitative question first, we decided start with the questionnaire and give them interview about why they give such an answer afterwards, in which way the research would be better structured. For analysis method of quantitative results we changed from Likert Scale to Semantic Scale which would give us more accurate result in this case. Within the questionnaire we also added questions of the most positive and negative emotions they feel about each screen, which are going to be evaluated also in scales.
We made different versions of the new displays for pilot study and received feedback from the nurses during the visit to Erasmus. The adjusted version of displays for pilot test is shown below.

- Future Plan

We will conduct the pilot study next Monday with 4 participants in a Care Lab.
On next Tuesday we are going to send the new version of measurement plan with results of pilot study to Agnes for feedback. Based on the feedback session (Thursday) we will conduct the final study on Friday in the Care Lab.

Visiting Erasmus

On 25.05 Anna and Doris visited the new ICU in Erasmus MC. During that time they had a tour around the facility, spend some time in one empty ICU unit and conducted an observation from 8:30-12:00. The notes from the study will be analyzed and the results will be presented next week. In addition, many pictures were taken for the context study which are included in a Drive Folder.
https://drive.google.com/drive/folders/1URA444SuKcZlhEjaQqF5v3AFLXbM188G?usp=sharing

During that visit they had also an opportunity to talk with clinicals. The main discussion topic was the display content in visitor mode. Six nurses shared their opinion about prepared examples and suggested changes. They have been already applied and are presented above in *PE Measurement Plan section.*

Next Week Schedule

Monday	Coach meeting at 11:00, PE Pilot Study
Tuesday	Meeting with Jacky on python coding etc. (IoT Guy)
Wednesday	Meeting with Elif about Friday's presentation at Erasmus MC
Thursday	
Friday	Presentation at Erasmus MC (3 people), PE study (3 people)

End of the week briefing 16, *08.06.2018*

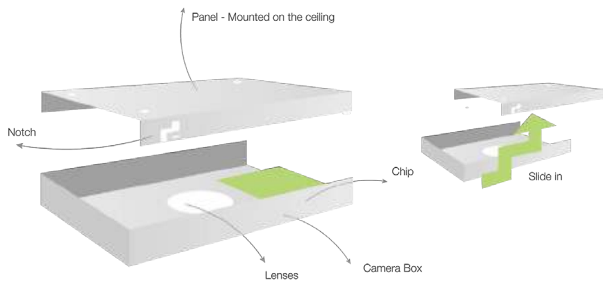
We took our project many steps further by almost finalising the overall appearance of our monitor and camera and coding for the beacons with the help of Mourad. Mourad, a freelance coder has helped us establish a web service with a local host that can make the app communicate the beacon status to the python that runs in the PC. Now we have the android application running on a mobile scanning the beacons and PC running the python code to showing the graphs. Both of these devices are stationary in a room detecting the beacons entering the room and going away. Now we are going to eliminate the android mobile be replacing it with a raspberry pi running a node.js application. Eventually python code will also be transferred to raspberry pi so that we have one small raspberry pi PC that does all the work and will be connected to a monitor. On the other hand, the camera module has also been simplified with raspberry pi zero. Now its a stand alone device that communicates wirelessly with the PC.

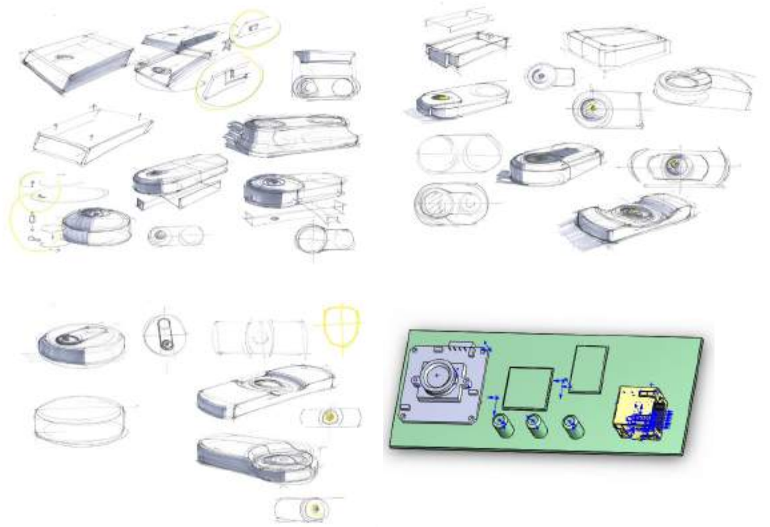
Today we have submitted the SDE report and finalizing the presentation. In addition, we have started CAD modelling of both monitor and the camera and we analysed the PE study results from last week. We hope to finish the CAD model and coding by next week and think about the presentation and movie making. Here are details down below.

Embodiment Design

1. Shape & Form

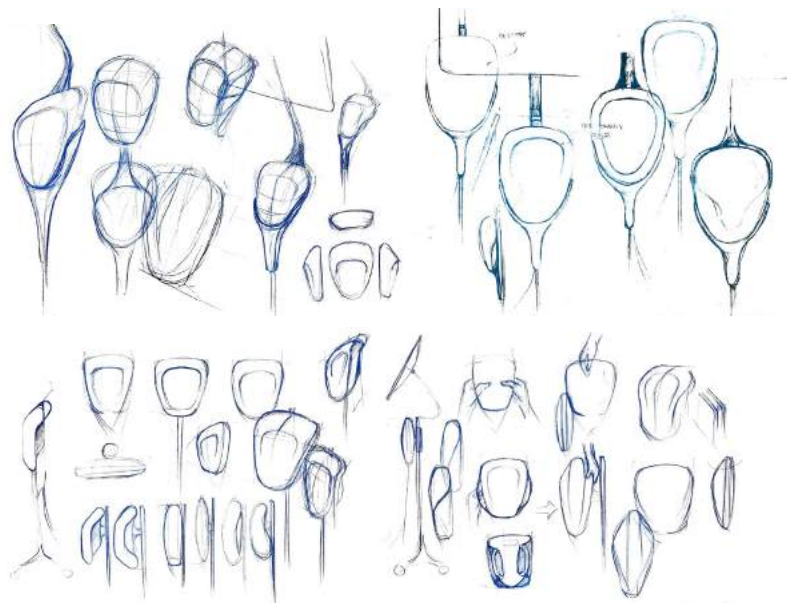
A. CAMERA

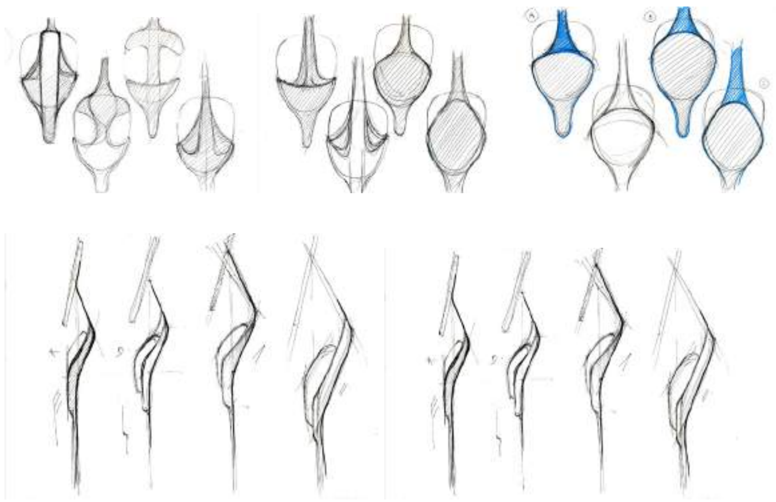




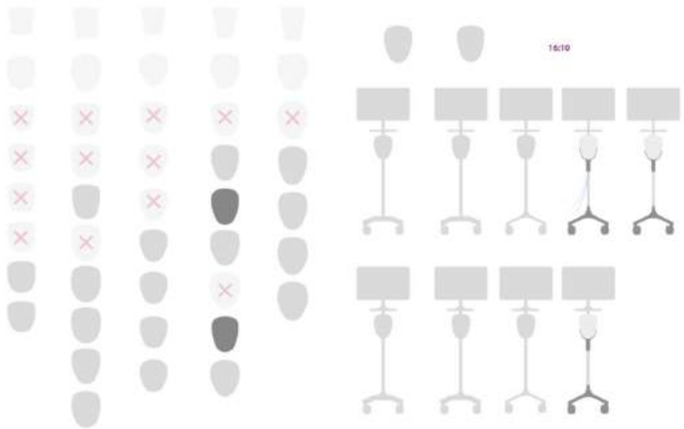
B. MONITOR

sketches

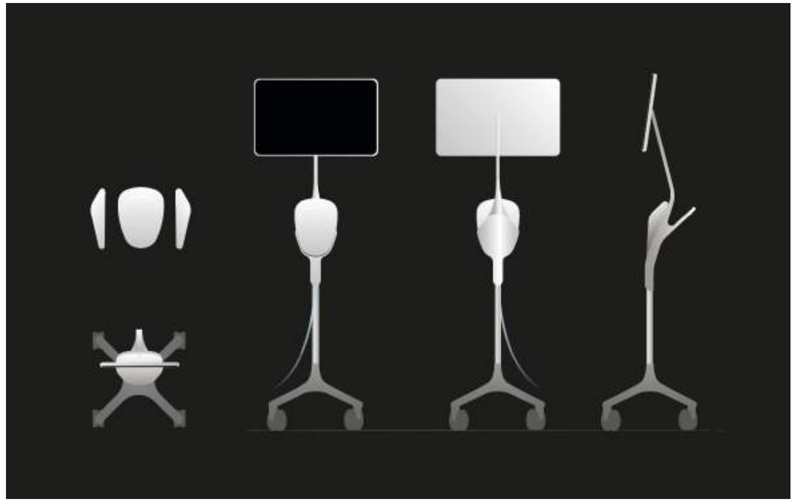


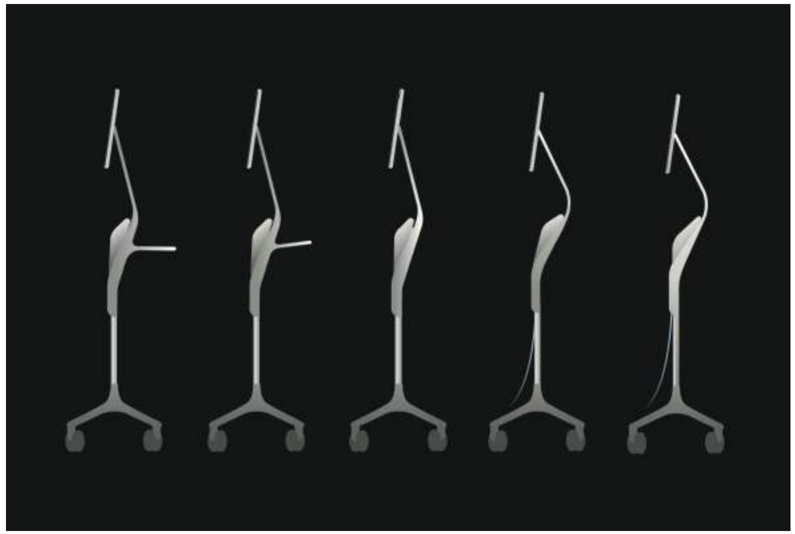


PC shape exploration



final sketches

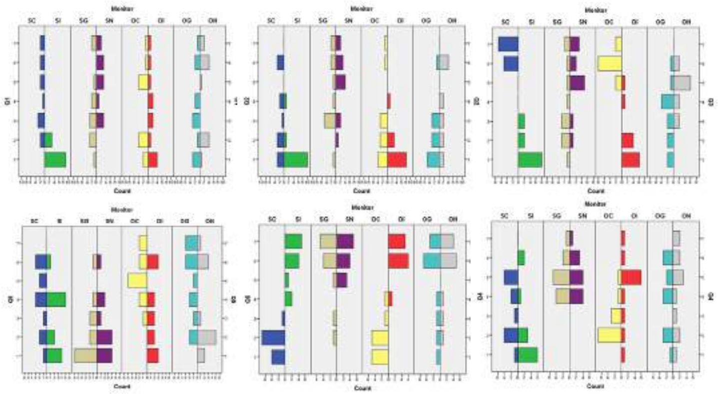




Prototyping

PE Measurement Study

Last Friday we conducted the research with 12 participants. This week we are in progress of processing data. For quantitative results we used one way ANOVA method to test the assumptions, the means for each question are also calculated for comparison. For qualitative results we finalized all of the insights brought by participants and grouped them by each question. Next week we are going to finish the paper and improve the display design according to the conclusion drawn from research.



ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
Q1	Between Groups	106,906	7	15,272	4,388	,000
	Within Groups	306,250	88	3,480		
	Total	413,156	95			
Q2	Between Groups	142,323	7	20,332	7,499	,000
	Within Groups	238,583	88	2,711		
	Total	380,906	95			
Q3	Between Groups	285,490	7	40,784	25,230	,000
	Within Groups	142,250	88	1,616		
	Total	427,740	95			
Q4	Between Groups	89,292	7	12,756	5,405	,000
	Within Groups	207,667	88	2,360		
	Total	296,958	95			
Q5	Between Groups	102,240	7	14,606	4,765	,000
	Within Groups	269,750	88	3,065		
	Total	371,990	95			
Q6	Between Groups	301,323	7	43,046	24,935	,000
	Within Groups	151,917	88	1,726		
	Total	453,240	95			

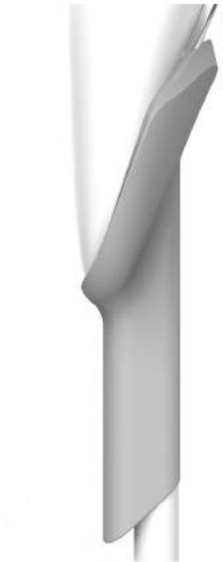
Garden update

End of the week album 17, *15.06.2018*

We're closing in to the end of this project and the product and prototype starts to take shape. This week we finished everything for the sustainability part of the project, concluding with a video on our project.

We got our hands dirty while making silicone prototypes of the beacons using a mold, cornstarch, food coloring and silicone. Although the first tries were a bit of the mess and it smelled awful, we managed to create some pretty neat prototypes after some practice.

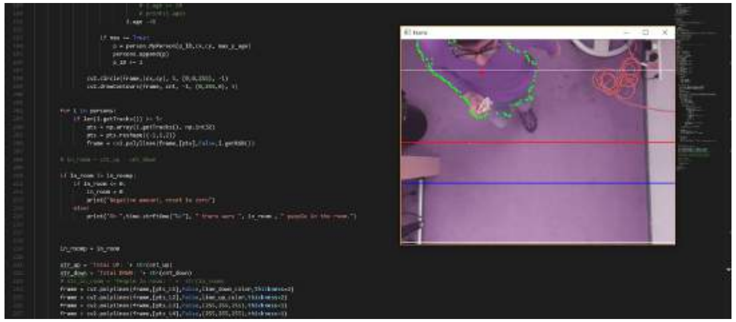
Furthermore, we made use of the 3D printers that were at our disposal. We printed various versions of our beacons for the mold, the computer, its basket and the camera casing.

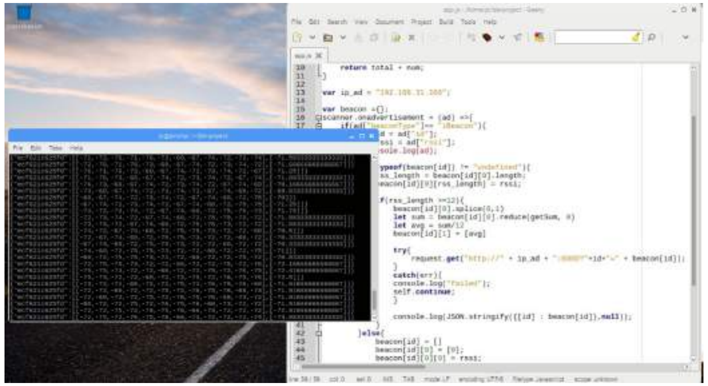


Prototyping

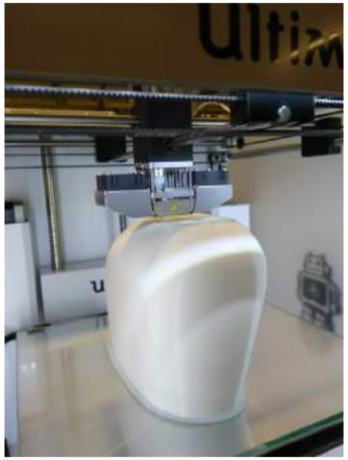
- **code**

Finally all parts of entire system is working as one. The raspberry zero is used as an ip camera which is used to detect people going in and out. A second raspberry is used to scan for nearby beacons. The video feed from the camera and the list of beacons are retrieved from local servers. The python program interprets the data and changes the screen accordingly. Both the camera and the beacon detection should be improved. The system is roughly 90% accurate, but more testing and adjusting is necessary.



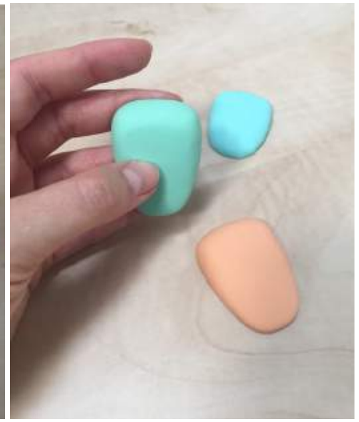


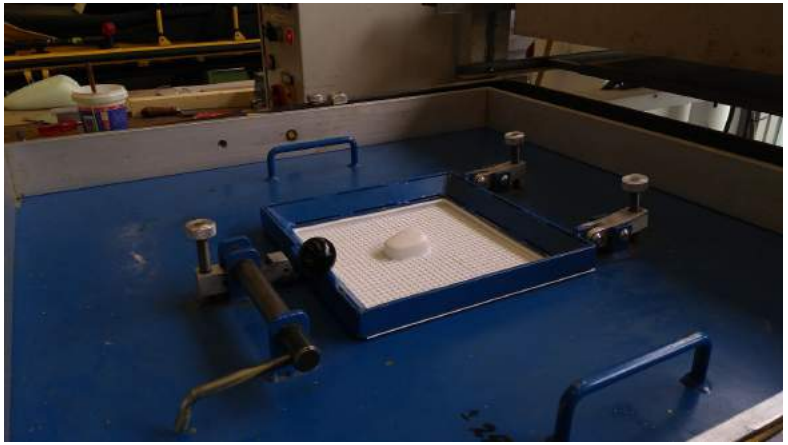
- **PC**



- **Beacons**

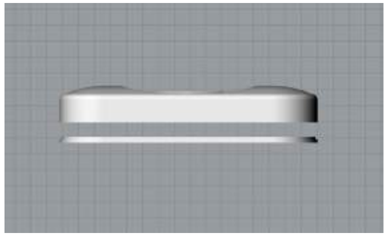
We started with 3D printed models of the beacons, which are smaller versions of the computer. These models were then used to thermoform sheets that resulted in the molds for the silicone beacons. The beacons were made using silicone from a tube, mixed with cornstarch to make it moldable and food coloring to colour the silicone and activate it. This worked pretty well and resulted in nice beacons. Now we have an idea how it works and which recipe works we can make a beacon that includes the electronics from the estimos. The beacons will be glued to hospital cards that clinicians wear. Those cards have been designed and will be ordered.

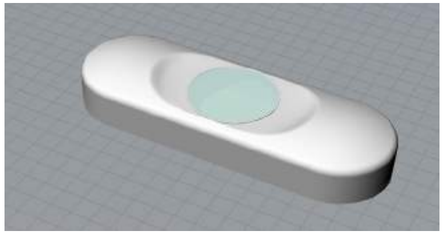




Camera

CAD Model

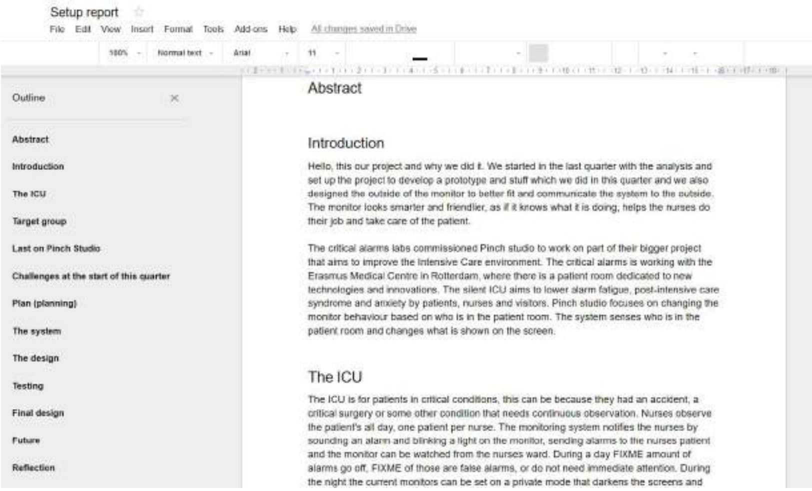




Started report

Since the end is coming near, we started on the report. Checking what we want to include and how we should include it. We looked at the various learning goals to see if we were missing components.

A general setup of the report was started and Doris started to write some parts that could already be written. This way we hope to not be overwhelmed by the work the report takes when we fully start to focus on this.



Setup report

File Edit View Insert Format Tools Add-ons Help All changes saved in Drive

Outline

Abstract
Introduction
The ICU
Target group
Last on Pinch Studio
Challenges at the start of this quarter
Plan (planning)
The system
The design
Testing
Final design
Future
Reflection

Abstract

Introduction

Hello, this our project and why we did it. We started in the last quarter with the analysis and set up the project to develop a prototype and stuff which we did in this quarter and we also designed the outside of the monitor to better fit and communicate the system to the outside. The monitor looks smarter and friendlier, as if it knows what it is doing, helps the nurses do their job and take care of the patient.

The critical alarms labs commissioned Pinch studio to work on part of their bigger project that aims to improve the Intensive Care environment. The critical alarms is working with the Erasmus Medical Centre in Rotterdam, where there is a patient room dedicated to new technologies and innovations. The silent ICU aims to lower alarm fatigue, post-intensive care syndrome and anxiety by patients, nurses and visitors. Pinch studio focuses on changing the monitor behaviour based on who is in the patient room. The system senses who is in the patient room and changes what is shown on the screen.

The ICU

The ICU is for patients in critical conditions, this can be because they had an accident, a critical surgery or some other condition that needs continuous observation. Nurses observe the patient's all day, one patient per nurse. The monitoring system notifies the nurses by sounding an alarm and blinking a light on the monitor, sending alarms to the nurses patient and the monitor can be watched from the nurses ward. During a day FIXME amount of alarms go off, FIXME of those are false alarms, or do not need immediate attention. During the night the current monitors can be set on a private mode that darkens the screens and

Garden