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FUN WEIGHT

A project for:

Final report

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TITLE: Fun Weight Final Report

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1. Abstract

The main objective of the Fun Weight project was to decrease the level of anxiety from children during preoperative treatment, while the gathering of measurements essential for further hospitalization takes place. This assignment has been conducted by an international and multidisciplinary team whose members were from fields of: Product Design, Electronics and Information Communication Technologies, Mechanical Engineering and Information Technology. The project was interesting and constructive due to tight cooperation with the Hospital de Sant Joan de Deu in Barcelona which was the main stakeholder of this project.

Methodology of the project consisted of in advance strictly defined steps, which were: researching, designing of the interactive game, designing/development of the application, prototyping of the application, prototyping of the interactive game and testing. However the development of the interactive game and the application have been performed simultaneously.

The outcome of this project has reached its end at the 17th of June and concluded following three elements: electronical prototype of the interactive game, three dimensional model of the game and the mobile application for retrieving measurements and communicating with the interactive game.

The stage of testing was divided into three independent sections: testing of the application usability, testing of the application functionality and evaluation of actual anxiety decreasing. As a result of application usability test, an average rate of ease of the interface has been obtained at the level of 2 what states for *easy to use*. Functionality tests have been performed with application of the *Angel Sensor* in function of the measuring device. In spite of problems encountered during the use of that sensor, basic functionalities of the application have been confirmed. Due to the shortage of the time, evaluation of decrease of anxiety level has not yet been conducted.

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4. Introduction

4.1. THE CONTEXT

4.1.1. European Project Semester

The European Project Semester (EPS) is a project-based learning program that involves multidisciplinary and international cooperation. Our group is carrying out a project in collaboration with Pediatric Hospital of Sant Joan de Deu and is comprised by the following participants: Pagona Manitara who studies Product Design in England, Anzhelina Adriyanovna from Belgium who is studying Electronics-ICT, Manel Vidal from Spain; a Mechanical Engineering student and Jakub Walczak who studies Information Technology in Poland. This project is supervised by Marta Díaz Boladeras from the department of business organization and Cristobal Raya Giner from the department of systems engineering and automatic control in the Universitat Politechnica de Catalunya.

4.1.2. Hospital of Sant Joan de Deu

Among all pediatric clinics in Europe Hospital of Sant Joan de Deu is most known for being one of the most established pediatric hospitals in Europe that has successfully adapted a patient - centred approach is the hospital of Sant Joan de Deu in Barcelona. It is worthy of mention, that it is the first Spanish pediatric clinic, which includes a dedicated department that is delivering innovative solutions and research. The investigation in Sant Joan de Déu is focused on Neurologic diseases, cancer, infectious diseases and pediatric development. Moreover, it carries out fundraising charity work that foments cultural and social progress within the scope of its operations. In addition, the hospital is heavily supporting the cooperation with external professionals and institutions. One of these partners is Escola Superior d'Enginyeria de Villanova i la Geltru, that maintains collaboration with the hospital the last 3 years in terms of the European Project Semester.

4.2. THE PROBLEM

One of the main goals of the Hospital of Sant Joan de Deu is to provide friendly environments and processes, in which medical and child care are linked in order to enhance the experience of the hospitalized children [1].

Children's preoperative anxiety is a challenging complication that medical staff frequently faces with younger patients. According to an estimation, 60% of children who are being prepared for an upcoming surgery experience significant anxiety before anaesthesia induction and surgery. [2] Although anaesthesia is a surgical procedure which blocks children's memory so as not to recall the surgery happening, the patient is still exposed to stressful events while preparing for the surgery such as pre-surgery vital signs measurements. It has been noticed that there is a connection between unsatisfactory anaesthetic inductions and pessimistic behavioural changes. [3] Moreover, there are studies in which is proved that the preoperative anxiety is linked with postoperative behaviour. Moreover literature is indisputably concerns preoperative anxiety as an international problem [4].

To help reduce the preoperative anxiety the nurses use a patient centred approach and attempt to provide child friendly environment. However, some hospitals are already using more innovative solutions like virtual reality.

4.3. OBJECTIVES

The aim of this project is to create a system which focuses on user experience and is based on interaction between the patient and the nurses in order to obtain the following measurements of:

- temperature
- oxygen saturation
- heart rate
- weight

However, the most fundamental objective of this project, is to develop a system which alleviate the stress and anxiety that accompanies children's illness or hospitalization.

Considering that Sant Joan de Deu hospital is a leading centre in its field that incorporates innovative technologies, the approach that has been suggested for this project is also a quite contemporary one. More specifically, our initial proposal encourages the use of latest wearable technologies in particular a smart wristband, combined with a traditional projector that has already been used in the hospital area. In addition we have to emphasize on the usability of the system, in order to provide a time efficient and accessible solution for both patients and medical staff.

5. Research

5.1. PSYCHOSOCIAL ASPECTS OF HOSPITALIZED CHILDREN

5.1.1. Anxiety of children in hospital

Introduction

Hospitalization can be a quite confusing and a stressful process for children and adolescents. The fact that they have to get separated from their families, cooperate with unfamiliar faces, go through unknown procedures and the fear of future pain maximizes the child's anxiety level before and after surgery. This kind of condition known as preoperational anxiety is a worldwide reaction that patients experience before their upcoming surgery. Only the idea of getting a surgery can bring extremely high levels of anxiety in patients. Preoperative anxiety is a troublesome state of tension and discomfort that derives from patient's doubts and fears before the operation [1]. Excessive anxiety and stress can affect children's physical and psychological health, hinder their ability to cope with surgery, encourage their negative behaviour in association with health care, and may also inhibit their post-operative recovery [2].

The separation of their parents is a quite unpleasant situation for the kids as they get out of their comfort zone, in an environment that most of the times does not look friendly and circled by strangers. Also the fear for the upcoming surgery and the pain that it will probably cause are common concerns that they express before the surgery. Moreover, another factor that may cause negative feelings, is the fantasy of the children which can create distorted ideas about hospitalization and their body image after the surgery. Depending on the type of surgery and the child's developmental age and level, kids might appear concerns for their school re-entry and fear of body mutilation.

Hospitalized children are also worrying about where their parents are, during the surgery and what they are doing. The parental involvement in the process of surgery and the stages before it is quite important for providing the children the emotional balance that they expect. Having parents present during preparation could provide the child with familiarity and security despite being in a strange environment. Additionally, parental monitoring not only increases trust, bust also enhances parents' perceptions of professional competence and quality of care.

Figure 1: http://www.colourbox.com/

Factors that influence children experience at the hospital

There are many factors which influence the level of stress that kids face before the surgery. Age, developmental level, prior hospitalizations, and prior encounters with the medical profession are the most significant ones. Moreover, coping styles of the child and the parents, as well as the parenting style, also affect coping behaviour [3].

Family and parenting styles

According to previous research, children whose parents have high levels of anxiety are more fearful, stressed, nervous and concerned, compared to the children whose parents are calmer. Preoperative parental anxiety has been shown to cause increase in children's anxiety, not only during the surgery but also in in the postoperative stage. In addition the level of stress also vary according to the type of the family structure. For instance, mothers who have adopted a kid perceived higher levels of stress than those who are biological mothers.

The impact of pediatric illnesses and disabilities on family stress has been documented several times. As Children's healthcare is a quite sensitive subject because of the young of its age, parents most of the time overreact while they are trying to protect their child. Many of them, combine previous experiences of hospitalization that they had in the past with the surgery that is approaching and stress themselves even more. However, evidence proved that parents' stress has important implications for the child's health and behaviour. According to studies, the parental stress for the surgery could be easily transmitted indirectly to the child and could also have important power to kids' recovery. On the other hand, when the kid is less anxious the parental stress level is being significantly decreased.

Gender

Researches shown that there is no connection between the sex of the child and the level of the anxiety, with both girls and boys facing the upcoming surgery with similar psychological perplexity.

Previous experience

Based on the Yale preoperative anxiety scale [4], children exposed to previous hospitalization may be more upset, anxious, or vulnerable. Children with previous bad experience are been negatively influenced by linking the two hospitalization experiences.

Situational factors

Moreover, Young patients' anxiety is been also modified by situational factors. When there are too many people in the room of the preparation and anaesthesia. The duration of the waiting stage, from the entrance in the room till the induction of anaesthesia, are also factors which can influence the child's mood. Stress increases significantly with the addition of hospitalization days.

Evaluative changes in children copying styles and needs

It is important to mention that according to age children are separated in four different groups: from one month to two years old, two to six years old, six to twelve and adolescents. As this project is addressed to kids from three to ten years old, the categories that we will focus on are the second and the third ones.

Most kids that belong to the second category of two to six years old are not ready to be independent but they want to participate and make choices. At this age kids' imagination is running wild and sometimes they suffer from nightmares and more fears. Depending on the type of the surgery and the child's development, kids may create distorted ideas not only about hospitalization but also about their body image after the surgery. In the psychosocial stage of initiative versus guilt, children become egocentric, and thus believe that they caused their own illness and that it is a form of punishment.

As those kids are quite young, the separation from their families and intimate environment, is increasing their stress levels. In those cases, kids are encouraged to bring some personal objects, like toys or blankets from their houses so as to feel more comfortable. Moreover, the absence of parents can raise quite stressful feelings. Children at this age, are usually attached to their parents, and that pose a great challenge for the nurses who are transporting the kids to the surgery unit, with kids' stress to continue during the induction of anaesthesia and when they wake up before their parents arrive in the post-anaesthesia unit. Therefore, parents are encouraged to inform the kids which hours they will be away, who is going to be with them for this time period and how can they contact them. Hospitalized children are also worrying about where their parents will be, during the surgery. The parental involvement in the process of surgery and the stages before it is quite important for providing the kids the emotional balance that they expect. Having parents present during preparation could provide the child with familiarity and security despite being in a strange environment. Additionally, parental monitoring not only increases trust, bust also enhances parents' perceptions of professional competence and quality of care.

Kids from the third category are more independent from their parents. Peer relationships and socializing with other kids is more important, however sometimes they appear concerned for their school re-entry and have fears for their body image. Moreover kids at that age, are quite sensitive with body examinations. They don't feel comfortable with being naked. It is critical that they do not feel embarrassed and they get the privacy that they want.

In this age group, children do understand more, so it is quite important that parents avoid having serious medical conversations in front of them. But at the same time, kids should not feel like being severed from the communication between doctors and parents. It has been suggested that unfamiliarity or lack of information about the hospital setting is a major determinant of psychological distress associated with pediatric hospitalization [5]. Therefore it is important to include children in the conversations when the medical staff enters the room. When they feel like they are included, they believe that they have more control over the situation and the perception of a threat would decrease.

Competing child anxiety

As it has been shown surgery can affect children wellbeing dramatically and it can have a serious effects for both kids and their parents. As Health care team is continually facing the problem of not obedient kids, they have been developing new approaches that would alleviate the stress and anxiety that accompanies hospitalization. Nurses, surgeons and child life specialist's collaborate in a multidisciplinary way which would benefit all the stakeholders.

Here we discuss what the components of children anxiety are, the importance of the care-giving team and the different approaches and interventions designed for alleviating children and family anxiety and to improve the experience at the hospital.

Care-giving network

The involvement of the nurse in the hospitalization of the kid is proven to be helpful and can be quite advantageous for both the child and the parents. Most of the time the parents' stress is emerging from the lack of knowledge as for the surgery. Sometimes, parents even trick their children and lie to them about the future of the medical procedures. However, nurses are the most suitable people to provide all the necessary details to both parents and children for the process of the surgery. Their education and experience helps them reshape the view of the situation, enhances and adds to their ideas about what to do about the problem, cheers them in their successes, and helps with reappraisal and identification of new coping strategies if coping attempts do not bring the desired responses. It has been suggested that unfamiliarity or lack of information about the hospital setting is a major determinant of psychological distress associated with pediatric hospitalization [5].

Child life specialists, is a new group of professionals which focused in the child development when they face high stress and anxiety during their hospitalization. They can have a double role, since they help kids to cope with preoperative stress, but they also educate their parents when they have inquiries, feel fear and risks of the processes. Child life specialists are supporting nurses by understating kids' perception and fears about the surgery that cause increase of the stress and denial in interplay with the nurses. Another, less popular technique is to use clown doctors, medical staff who are not necessarily doctors, but they dressed up like doctors in clown dresses and are taking part in the pre-surgery stage, a method for preoperative teaching or distraction of preoperative anxiety in children [6].

As it was mentioned before it is quite important for kid's calmness to engage them in the communication between doctors and parents. When a medical member approach the kid, talk to his eye level, makes the kid feel more comfortable. By conversing with them, ask simple questions about their choices and their preferences, would also feel like they have a little more control in the situation. However, it is preferable when only one person is involved and talking with them. If too many people are talking simultaneously, children cannot focus and being distracted by all the conversation that is going on. In addition, medical staff and parents should avoid using complicated words and acronyms, because kids may get confused and misunderstand the meaning by relating it to something bad.

Information and involvement

At this point the psychological support and education that hospitals provide in both children and parents it is quite helpful for overcoming the anxiety. Intensive psychological intervention, could have different forms, either a nurse's introduction to the child before the surgery, or a leaflet that could be provided in the first visit in the hospital or group meetings with other hospitalized kids or websites with detailed report of the following procedures. Also, a good communication between hospital and parents is crucial, as the latter have to provide encouragement to the child for the upcoming separation while promoting a positive transition to the medical staff.

Moreover, it is important for both kids and parents to have a control of the hospitalization. It was believed that through demonstrating and return demonstrating the medical procedures, such as applying ECG electrodes, pulse oximeter, blood pressure cuff, anaesthesia mask, and intravenous catheter on the doll, the children would have fun, get desensitized to potential stressful situations, be able to alleviate their anxiety towards threatening procedures, and also get instilled with a sense of control over the situation in which they were involved.

For parents' psychologically balance, the supervision of their children and their involvement in it can be quite stress relief. That is not only because they will be next to their kids but they also have the freedom to control the medical staff's treatment. As the medical staff is responsible for a big amount of hospitalized children, it is quite common that they cannot spend a lot of time to each kid individually, in cases of bad mood or resistance to eat. In these cases parents have a more caring behaviour and are willing to invest more time to their kids.

Ideas that could be incorporated so as to eliminate the stress of both kids and parents: Books that children could get in their first visit at the hospital and then bringing them back in every visit, that is being updated with stickers and images that help them control the process and having a small reward out of it.

Conventional Interventions

Alternative approaches for calming down the kids before and after the surgery have also been developed in recent years. Music therapy is one of the options which have been widely used for both children and family members in pediatric clinics. The use of music could be either writing songs, where kids can express their feelings for the upcoming surgery or just using different instruments for rhythm development for nonverbal kids. Studies have shown that music therapy helps kids for relaxing and sleep and limits the need for pain control medication for recovering from the surgery. [7] In general, music therapy seems to be more helpful for the child after been separated by its parents and upon getting in the surgery room, however it depends on the therapist and the approach which is using.

Technology based and innovative approaches

Since most of the pediatric surgeries are performed in an outpatient way, the time that is being used for preparing the children is quite limited. As a consequence some hospitals have started engaging new methods which are time efficient for the preoperative stage. The use of computer games is one of the most common techniques which allows medical staff to provide information and instant communication with the kid. Nowadays, computer games seems to gain more and more the interest of kids, and in many developed countries is a big section of the culture of children and teenagers [8]. One of the advantages of computer games is that it can be personalized to each patient, offering guidance in an easy to understand way and preparing it for the following stages, while waiting for the undergo surgery. Moreover it captures kid's imagination and helps in familiarizing himself with the environment, while offering them the opportunity to participate in the virtual process. The kid is exposed in a safe and simulated environment, which is also interesting, and as a result is getting mentally prepared with less anxiety for the surgery. As the technology is being developed and trends are keep changing, preoperative processes have also to be developed and adapt more modern techniques according to children's interests and desires.

As it has been stated, in many cases children's anxiety about the surgery starts before they even left their homes [9]. For that reason many hospitals have started providing prior information and teaching for the upcoming surgery to both parents and kids. This information could have different forms, either a nurse's introduction to the child some days before the surgery, or a leaflet that could be provided in the first visit in the hospital or group meetings with other hospitalized kids or websites with detailed report of the following procedures. In that way kids understand better the procedure that have to get involved and as a result their stress is significantly been decreased. However the information should always be age appropriate and based on their anxiety level. According to studies, preparation given to the patients can be beneficial for children aged at least 6 years and older. Children older than 6 years old are less anxious if they have received preparation at least one week prior the surgery. Anxiety would be increased preparation was given just one day before the surgery. In any case, giving kids too much information or more that they can handle at their age creates anxiety [10].

5.1.2. Environmental influence

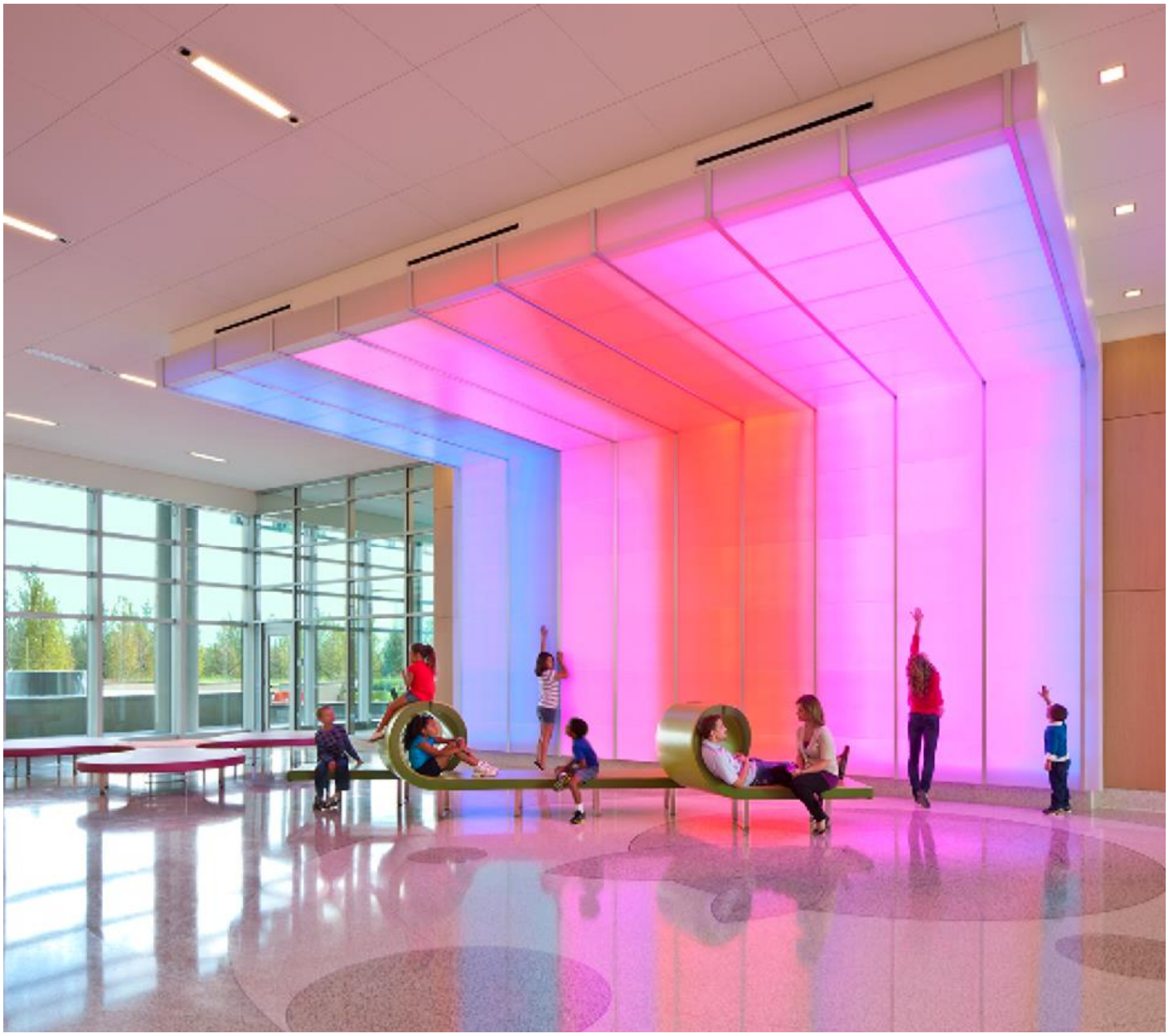


Figure 2: http://www.nemours.org/locations/nch/hospital-amenities.html

A well designed environment of a pediatric hospitals could have amazing effects in the patients by either ameliorating or exacerbating their distress. As it has been stated, most children and youth find hospitalizations stressful [10], still there is not enough research in this field.

However dramatic changes had taken place in the architecture of hospitals for kids in the last decades, so as to create a more child friendly environment. Beginning in the mid-1970s, social scientists argued that the windowless, maze-like hallways, medicalized interior landscapes and unusual ‘‘smellscapes’’ could generate feelings of ‘‘placelessness’’ [11] and thereby contribute to young patients’ distress [12]. Since the 1980s, these arguments have led architects to design pediatric hospitals intended to ‘‘de-emphasize connotations with institutionalized medicine’’ and to foster a ‘‘sense of enchantment’’ [13]. As it has been recorded, in order to succeed this and create therapeutic fantasies that kids feel more confident in them, they used specific design tricks, such as bright colours, natural lights, indoor foliage, park benches, water fountains, juvenile artwork, nursery images, mascots, film and television characters even fast food franchises with easily recognizable aromas. [14]

Hospitals, like all buildings, are both shaped by people and capable of shaping occupants' behaviours and feelings [15]. They are complex places that are simultaneously physical, social and symbolic environments [16]. Their designs are affected by developments in medicine, social values and political priorities, all of which are themselves affected by differential power relations. Inspired by critical social theories, recent thinking in ''post-medical'' and critical architectural geography casts hospitals as contested places that are occupied by multiple stakeholders and nested in particular socio-historical-material contexts [16]. Researches are addressed in two kinds of stakeholders in particular. The first one considers children as respondents. The omission of children in social science research on hospitals likely reflects their marginalized position as hospital stakeholders and in society-at-large [17]. Children and youth are routinely denied a voice as agents of architectural knowledge, even in studies of pediatric hospitals. The second one, is focused on the social and symbolic environment expressly to the degree that environment is controlled, shaped and made manifest by architects.

According to Ulrich [18], a "positive" distraction is an environmental feature that elicits positive feelings and holds attention without taxing or stressing the individual, thereby blocking worrisome thoughts. In a study of pediatric patients, children aged 3.5–12 years reported less pain during blood draws when encouraged to use a kaleidoscope [19]. In another study, children reported less pain during injections when distracted by touch and bubble-blowing [20]. In another case, breast cancer patients reported reduced anxiety, fatigue, and distress during chemotherapy when exposed to a virtual reality intervention displaying underwater and art museum scenes [20] .Also, heart rate measurements collected in a dental clinic suggested that patients experienced lower stress on days that a large mural depicting a natural scene was hung on the waiting room wall, versus days when the wall was left blank [20].

Art is a mean, which has been widely used in hospitals, particularly in pediatric clinics during the last years. The benefits of using art in healthcare environments are significant, as they help the patients not only by distracting them, but also reducing stress and anxiety and therefore enhance the recovery process.

However it has been noticed that most of hospitals, have not been synchronized in the modern world and interests or modern kids. Moreover, most of the times the selected themes are only appropriate for younger ages, and as consequence the adolescents (10-17) do not show any interest in the surrounded environment. Research also shows that adolescents do not appreciate blatant symbols of childhood such as teddy bears, clowns, and balloons [21]. Yet, the typical Disney-type image of fantasy and fun is rampant in healthcare, both in thematic design and art selection. Pediatric units are often bright, colourful, and covered with art that is considered appropriate— often according to an adult who has not consulted the actual stakeholders, children and young people [22].

According to Machotka (1966) children are usually evaluate paintings and art in three different ways of intellectual development. The first one, is the appreciation based on the subject matter and colours, from the start of the school, which does not require ant preoperative functioning. The second one that is for ages 7 to 11 is based on the realistic representation, contrast, harmony of colours and clarity of presentation. And the last one for kids from 12 years old and above, requires operational though and is evaluation is influenced by the interest in style, composition, affective tone and luminosity. However, according to the researcher, kids across all the age groups, refer realistic styles instead of abstractive and semi abstractive styles.

Trying to find out the kids' preferences and ideal pediatric hospital where they would feel more comfortable in is a quite challenging subject. It is difficult to measure functions like comfort, socialization, interface, way finding, contact with the nature and diurnal rhythms for creating the perfect hospital that contributes to kids' wellbeing. Most of researches have been focused, in architecture humanistic geography and in cooperation with medical staff and child specialists. However, addressing the main needs and what are the perceptions of the kids is not always related to what adults believe.

5.2. PREOPERATIVE PROCEDURES

There are three main stages in children's hospitalization is being separated. The first one is the preoperative procedures, then the surgery and last the recovery. The preoperative procedures are specifically designed so as to improve the experience and the outcome of the surgery, decrease the risk of complications so as to have a safer and more effective operation.

The journey of the hospitalization

Before going to the hospital for the upcoming surgery the patients who will receive anaesthesia, should not consume food or water some hours before the operation. However the time of fasting depends on the age of the patient. For infants with breastfeeding, the fasting should start three hours before and drink water up to two hours before the surgery. For babies older than 6 months could drink water up to two hours before, breast milk up to four hours before and bottle, baby food or a light meal up to six hours before the upcoming surgery. Older children can have some water, pear or Apple juices up to two hours before and food until six hours before the operation.

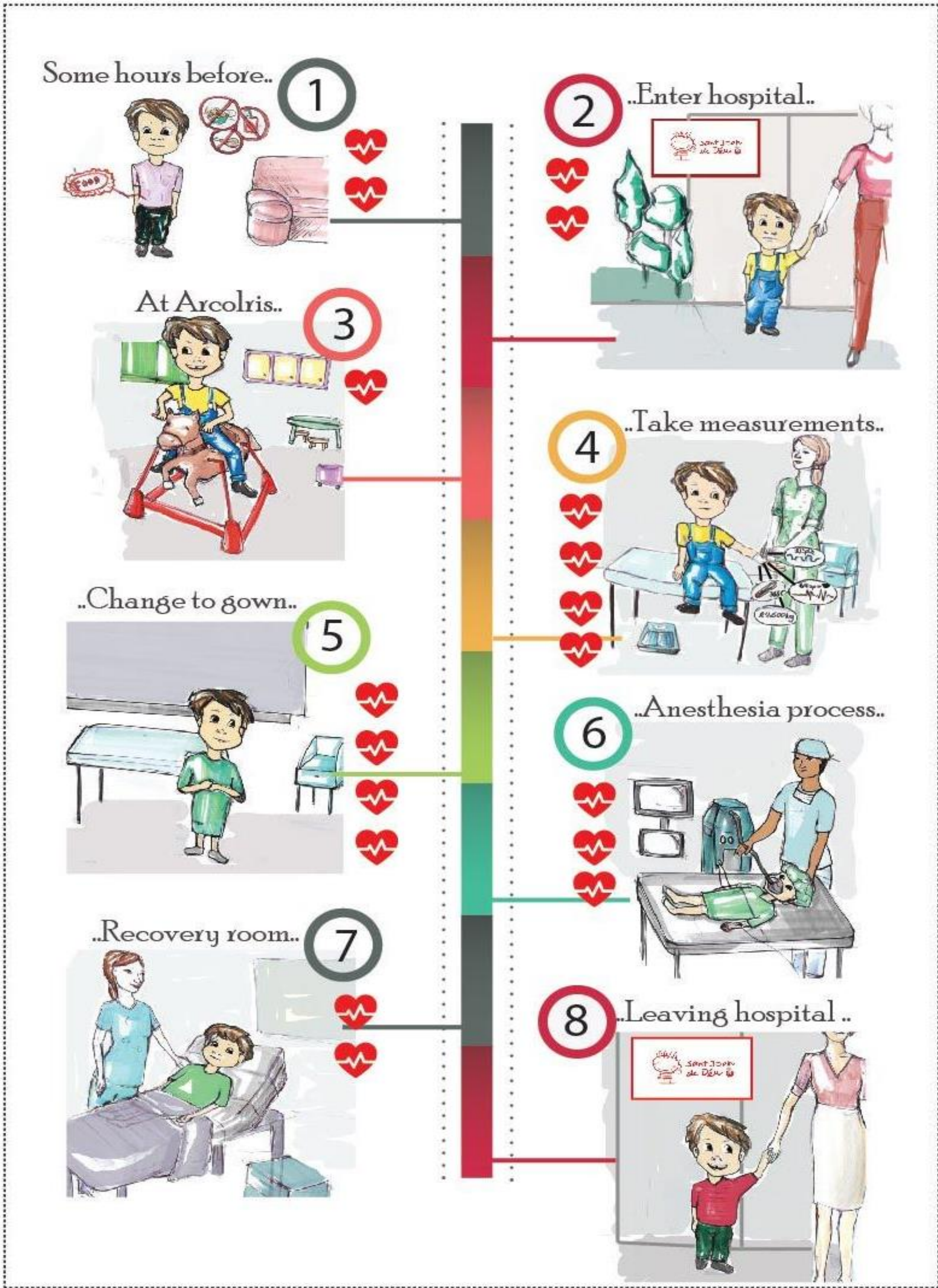
The patients that undertaking surgery on an inpatient basis are coming to the hospital at the same day of the operation, at least one to two hours before. Then they are going to the waiting room, a space which is called "Arcolris" (rainbow translated to English), where the nurse checks their state and all the paperwork. At this point the nurse checks the children and taking the basic measurements like heart rate, weight, oxygen rate, temperature. Then the patients are changing to either their own pyjama or to a hospital gown. However there are some exceptions to this process, which are the cases of serious operation like heart surgery, scoliosis and transplantation. In these cases the pediatric patient is coming to the hospital the day before the surgery and stays at a hospital room.

Afterwards, patients are moved to the operating room with an auxiliary nurse and the parents. There, the anaesthesia is provided to the child and the surgery takes place.

Immediately after the surgery is finished, the child goes to the "recovery room" for forty to sixty minutes, except cases of serious operations, which go to the intensive care unit. This area, is called post-anaesthesia recovery process (PACU) or “Post Anaesthesia Care Unit”. Later patients go to their room in the hospitalization area.

There are also patients who undergo a surgery, but they do not have to stay in the hospital the night after the operation. These are “Ambulatory Surgery” patients and they do not go to the Arcolris but at the clinic of the Day Surgery.

In the following image is presented a brief visualised storyboard of the procedure which children undergoing before and after their surgery. It is also indicated the level of stress that patients cope with in every stage.


Some hours before..
1
..Enter hospital..
2
At Arcolris..
3
..Take measurements..
4
..Change to gown..
5
..Anesthesia process..
6
..Recovery room..
7
..Leaving hospital ..
8

6. State of Art

6.1. INTRODUCTION

The measuring of a patients vital signs is essential to monitor the patience health, since they reflect on 3 essential body process for living organisms (regulation of body temperature, breathing and heart function). Standard medical measurement mostly consist of monitoring: temperature, weight, pulse, respiration and blood pressure (TPR and BP). Vital signs changes can indicate an illness and during treatment if compared to the baseline (vital signs measurement of the patient when he/she is healthy), they can indicate response to the treatment and the progress of the illness. Pulse oximetry (measurement of oxygen concentration in blood) is also considered a key indicator of health state of the patient, especially by patients with respiratory complains or a history with respiratory disease. The vital signs of a patient vary within certain limits. Some factors like in example fear, activity, age, gender, anxiety, anger, noise, pain, stress, illness, and many others, have an influence on the vital signs of a patient what also needs to be taken into account. Since even minor changes in a patient's health mostly will show by differing from the baseline vital signs accuracy is essential during measuring, recording and reporting them.

The importance and the significance of the vital signs which will be measured in our project will be separately discussed in the specific topics in the state of art.

6.2. EXISTING SYSTEMS

6.2.1. Radio-frequency identification

RFID is an emerging technology that is rapidly becoming the standard for hospitals to track inventory, identify patients, and manage personnel. RFID systems are seen as valuable because of their ability to collect data in real-time. As a result, these systems may have a valence toward surveillance, such that the location of individuals is tracked and analysed under the rubric of management paradigms like "workflow management." [23]

6.2.2. The effects of a hands-free communication device system in a surgical suite

This case report describes a qualitative investigation into how a Hands-free Communication Device (HCD) system impacted communication among anaesthesia staff in a pediatric surgical suite. The authors recruited a purposive sample that included anaesthesiologists, certified registered nurse anaesthetists, circulating nurses, a charge nurse, and a post anaesthesia care unit nurse. Data were collected using semi structured interviews and observations, then analysed using a constant comparison approach. The results corroborate and enrich themes that were discovered in a previous qualitative study of HCD systems: communication access, control, training, environment and infrastructure. The results also generated new subthemes and themes: technical control, choosing communication channels, and reliability. The authors conclude that HCD systems profoundly impacted communication in a largely positive way, although reliability of the technology remained an issue. The authors' findings contribute a valuable insight into the growing body of knowledge about implementation and use of HCD systems. [24]

6.2.3. The medical technologies that are changing health Care

Reflection of the current state of the technology applied to the hospitals and some examples we can find today [25]:

- Google glass aids trauma care
- Press-and-print body parts
- Battery-powered germ-killers
- The orderly robot
- A health check chair
- Fingertip surgery

6.2.4. *Cedars-Sinai* hospital adopts virtual reality

Cedars-Sinai Medical Centre is a world-renowned medical institution which is on the forefront of medical research. Alongside with *Mayo Clinic* and *Betty Ford Centre*, it is perhaps the most known medical 'brand' from the United States. There are many theoretical approaches to patient therapy and aiding the healing process, but only research work on the field can bring results or debunk theories. This is exactly what the medical experts at *Cedars-Sinai* decided to do by launching a virtual reality project. The Centre embedded several Virtual Reality devices in different aspects of patient therapy / treatment, and monitored the results. Medical trials included *Samsung GearVR* device, as well as *Oculus Developer Kit 2*. [26]

6.3. INNOVATIVE SOLUTION FOR MEASURING

Sant Joan de Déu-Barcelona Children's Hospital aims to be a Liquid Hospital, going beyond the physical building blocks of the hospital. *Sant Joan de Déu-Barcelona* Children's Hospital is the most relevant example in Europe where a hospital is using online care, telemedicine, mobile apps and health 2.0 tools to put the patient in the centre of care.

A Liquid Hospital is an initiative of *Hospital Sant Joan de Déu* which includes a number of related projects according to the new technologies while all of them having the same purpose:

Facilitate the attention of the patients beyond the Hospital walls, wherever they are.

Promote the exchange of knowledge between the professionals of different fields.

To accomplish this initiative, the Hospital has received assistance from the *Avanza Plan* of the Ministry of Industry, Tourism and Trade.

In agreement with this new way of thinking and giving health care the objective is to create a state of wellbeing of the patient according to the new technologies that are coming out recently.

Performance measures, regardless of their level, should be coordinated, or integrated to form a coherent system of measurement. A well-integrated measurement system might include features such as:

- ~ Selection of both macro- as well as micro measures for high-priority clinical conditions (e.g., cancer care), target populations (e.g., women over age 50) or particular areas of organizational focus (e.g., process efficiency) to reflect shared values throughout the system.
- ~ Use of identical definitions of key terms and measures for similar concepts (i.e., all medical/surgical hospitals in the system use the same inpatient satisfaction survey and present results in the same way).
- ~ Use of comparable diagnostic and procedure codes to identify target populations and services provided.
- ~ Use of the same financial data bases and accounting conventions to measure costs and revenues.
- ~ High degree of sharing and compatibility of specific data elements across system units (e.g., patient identifiers, work-unit identifiers, results reporting systems, and financial databases from which performance measures for many different operating units can be derived).

This integration is easier said than done. Many hospitals have "legacy" information systems which were present before the hospital joined a multi-hospital system, or which have been built over time as stand-alone applications. Physician group practices may have medical records systems and patient identifiers which are not easily integrated with hospital medical records or electronic results reporting systems. Similarly, health plans may record individuals as members of a "subscriber unit" with the same identifier for all members of the same household, with that identifier being different from any medical record number for any of those individuals in any of the member clinical facilities.

It is, in fact, more common in practice to find fragmented, rather than integrated data systems in health care organizations. It is unusual for a large multi-specialty group practice to have integrated medical record, appointment scheduling and billing systems. It is unusual for all hospitals in a multi-hospital system to share common patient registration, order entry, or ancillary systems. It is also unusual to have hospice, home health, rehabilitation, or social work units share information systems with other health care operating units.

Note, though, that all health care organization have information systems. These systems may range from the state-of-the-art to the archaic. They may be more- or less-integrated; paper, electronic, or both. Measurement difficulties arise not because of a lack of data; rather, they tend to revolve around a lack of ability to coalesce those data,(2) to create a support system in the form of information retrieval, display and measurement tools which allow data elements to be pulled together efficiently in order to inform appropriate action. And creating such tools may be less a matter of technology than it is of determination, cooperation, leadership, common sense and creative thinking about the resources that are there already. [27]

6.4. CONVENTIONAL SENSORS

6.4.1. Temperature sensors

Introduction

Thermometers are used for a really long time to detect illness and studies of water and habitats for example. The temperature is essential for the body to stay within a certain temperature range to maintain homeostasis (homoeostasis is the property of a system or organism to regulate itself so that the internal conditions of it remain stable and relatively constant). Temperature that falls above or under this range are mischievous for the organism, this is one of the reasons why temperature is monitored in a medical envoirment.

The first thermo scopes that had a scale started rising in the early 17th centuries. The thermometers we are used to see in the end of 20th century and the start of 21st century were the mercury thermometers.

Figure 3: Mercury Thermometer

These are not so often used anymore because of the mercury which is poisonous, and since the thermometers were mostly made of glass it was dangerous to use them. They work on the basic liquid thermometers principles. When in contact with heat substance within the thermometer shall have a thermal substance expansion, on which after calibration is put a scale. (So the amount of fluid in this case mercury is in every thermometer the same and so by changing the temperature by some degrees the fluid will expand or contract by the same amount of volume. Which is measured and put on scale.)

Right now the electronic thermometer rose in popularity in the most households.

Figure 4: Electronic thermometer

Mostly because it is safer and more user-friendly. The electric thermometers use the probe at the tip too sense temperature by increasing/decreasing the resistance in the circuit which will be measured by it and interpreted (calculating the temperature on the desired scale). The result is then shown on the display. The accuracy of these thermometers is pretty good and the fact that the tip isn't dangerous for the patient (like the bulb of the liquid thermometers mostly was) makes them so popular.

Figure 5: Infra-red thermometers

There are also pyrometers which are thermometers that don't require contact too measure the temperature one of the most beloved of these is the infra-red thermometer or the ultraviolet thermometer.

This thermometers detects the thermal radiation produced by an object or living being. They mostly consist of a lens that is focusing the infra-red thermal radiation onto the detector. The last will convert the radiant power into an electronic signal that after interpretation shall display a value of degrees on the display. Although the accuracy and precision of this thermometer are often put under question, their speed of measurement and the comfort result in still usage of this types of thermometers.

Comparison

Temperature sensor:	**Operating Temperature Range:**	**Maximum Permissible Current:**	**accuracy:**	**Protocol:**	**Price:**
 ***Figure 6: JY-XY0925253 Temperature sensor***	≈-20℃~150℃	2mA(at 25°C)	Calibratable		0.3-5$
 ***Figure 7: JY-XY0925230 Temperature sensor***	-20℃~150℃	2mA(at 25°C)	Calibratable +waterproof		0.35-5$
 ***Figure 8: 0065NS1J0080D0115T44 Temperature sensor***	–50~450 °C (head-40°C~+85°C)	0-10V	±0.02% of span	HART	5$
 ***Figure 9: KKM03 Sensor Temperature Data Logger medical thermometer***	25°C-55°C		±0.05°C(36°C-41°C) & ±0.1°C(25°C-36°C and 41°C-55°C)	Android and IOS, Bluetooth 4.0	5-11$

Table 1: Comparison Temperature Sensors

 ***Figure 10: ADT7420 Temperature sensor***	−40°C to +150°C	2.7 V to 5.5 V	accuracy: +/- 0.25oCat 3V slow temperature drift: 0.0078oC		45$
 ***Figure 11: TMP01 Temperature sensor***	−55°C to +125°C	20 mA open-collector trip point output	accuracy: +/- 1.0oC	user programmable	5.5$

Conclusion

After reviewing the possibilities it was decided to use JY-XY0925253 Temperature sensor based on its calibratable accuracy and the fact that it is waterproof. This sensor is easy to implement in any system and with the right calibration it meets the accuracy (0.1 degree of Celsius) which is required. The low current requirement of this senor is also advantageous to us since we can use the microcontroller provided current.

6.4.2. Weight sensors

Introduction

Weight is not one of the primary vital signs but is an important factor which can show the state of health. By monitoring the weight it can show the level of dehydration, it also is used to calculate the fat percentage of a patient. During procedures the change of weight is a response to the treatment, which can indicate whether it is effective or not. Losing weight is also seen as a symptom of illness in some cases.

The weighting scale has two main category's the balance which is the oldest and the force measuring scale. The balance is used for centuries, there are even old Egyptian drawings in which we see their usage of the balance. The Principe is simple, the balance will measure the weight of its first arm against the second one. So if you have a certain weight like 1kg in one arm you can measure the weight of the other arm by putting extra weight on that till it is equal to 1kg. This method is not really accurate and not precise.

So after time the force measuring scale was invented in the 18th century. They became widely used (mostly in England in the early stages) in the 19th century. One of them was the spring scale. This type of scale is a mechanical scale. It measures the force with which the object is pulled towards the earth (gravity applies 9.81N of force for each kg the object possess) and knowing the force it calculates the mass (F=m*g ⇔ m=F/g). Like that the scale on the sides is applied. (For every 9.81N the spring is extended by X length. And every X the spring is extended there is a mark which will show us how many kg we actually are applying to the spring scale.)

Figure 13: Human Balance Scale

Figure 14: Spring scale

Figure 15: Digital scale

The digital weighting scales we know today are based on a Wheatstone bridge with 4 loading cells to measure the weight. A load cell will change the resistance it have by the strain that is put on it. And the Wheatstone bridge works as a voltage divider. (with two fixed resistances and 2 variable so that the difference between the two other is measured and converted in an electric signal which will on its time be interpreted by the circuit and show us the weight on its display.)

Comparison

Weight	Rated Load:	Power Supply:	accuracy:	Protocol:	Price:
 ***Figure 16: CW268BLE Body Weight Scale***	180/250kg	4* AA	0.1kg	IOS & Android Bluetooth 4.0	1-15$
 ***Figure 17: CL381 Scale***	50kg	1xCR2032	0.1kg	none (need someone to read value)	3$
 ***Figure 18: Xiaomi Mi smart scale***	5kg-150kg	4 x AA	5 ~ 50kg: ±0.1kg; 50 ~ 100kg: ±0.2kg	Bluetooth 4.0 Dedicated for Android, IOS	

Table 2: Comparison Weight Sensors

Conclusion

Accuracy is an important factor when a sensor is chosen. CW268BLE Body Weight Scale meets our requirement of accuracy and measures up to 250 kg, so it is suited for our system. We need a scale that measures a high weight without sacrificing accuracy of the measurement for it. Since not only the child but also a part of the whole system will be measured we need a scale that can handle weight above 150kg, and also to this requirement is suficieted by the CW268BLE Body Weight Scale.

6.4.3. Heart Rate sensors

a) Introduction

The heart rate is an important medical parameter that often show us the fitness (healthiness) of one's heart and its stress level.

The heart rate can be measured in two ways (most common), manual by finding a person's/animals pulse and count it during an amount of time (mostly 60 sec or 30 sec). Like that you have the bpm of the heart. The other way is the electronica way, with mostly an ECG or heart rate monitor. The ECG generates a pattern which he extract from the electrical activity of the heart. There exist 3 ways to calculate the heart rate in bpm from this pattern.

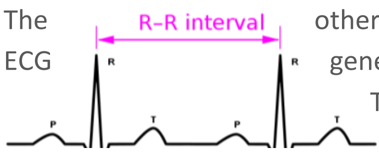


Figure 19: ECG Pattern

- ~ The first one is HR=1500/RR (in mm). If we look at an ECG in mm paper we see that each min consist of 1500mm or 15 cm so we measure the length in mm between the two waves (peak to peak= R to R) and we divide the total length during one minute with the length of a wave which will result in the bpm we need.
- ~ The second one is HR=60/RR(in sec).Since we need bpm we take 60 sec and divide it by the time that is consumed for one full wave (measured from one peak till the other start of the peak, R to R). This also results in bmp (HR).
- ~ The third way is HR=300/N big squares between the two wave tops (R). 300 big squares is the place taken by one minute in time.

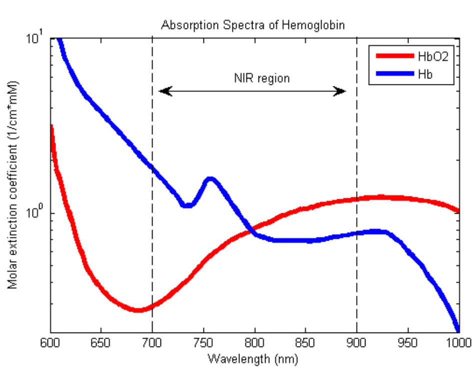


Figure 20: Absorbsion spectra Hemoglobin

The most sensors aren't based on this technics. The most use the pulse oximetry as a measurement of HR. This technics basically uses the fact that oxygenated blood and de-oxygenated blood have different optic values. And so it calculates the amount of oxygenated/de-oxygenated peaks during one minute which will result in bpms (HR). This is the technic that our sensors also will use for calculating the HR.

b) Comparison

Oxygen saturation	Measuring data:	Power Supply:	Place measurement taking:	Protocol:	Price:
 **Figure 21: BM1000B sensor (HR and OS)**	spo2, pulse rate, pulse intensity, plethysmogram	2 AAA batteries	Fingertip	Bluetooth 4.0	40-45
 ***Figure 22: CMS-50D sensor (HR and OS)***	SpO2, pulse rate	2 AAA batteries	Accuracy: +/-2% Resolution: 1% for SPO2 Pulse Ratio 30 - 250BPM Resolution:1BPM	stored data can be uploaded to computers	30$

Table 3: Comparison HR and SO2 sensors

The comparison of the oxygen saturation and heart rate sensors is both in one. Sine we want to use hear rate sensors based on the pulse oximetry technic. Mostly also smart sensors have more than one measure they take just like this one, but this we will discuss later on.

c) Conclusion

Based on the parameters CMS-50D sensor (HR and OS) seems the best option. The requirements of accuracy are met and it is easy in use. The implementation of this sensor to our system can be difficult since it doesn't have wireless communication option. With adaptation this sensor can be used to communicate with a microcontroller which makes it usable for our circuit.

6.4.4. Oxygen Saturation sensors

Introduction

Oxygen saturation (symbol SO2) measures the amount of oxygen that is taken in (dissolved in most cases) or carried in a given medium, which in our case is blood. It can be measured with a dissolved oxygen probe such as an oxygen sensor or an optode in liquid media. The oxygen saturation is presented I units of percent (%). Oxygen saturation can be measured regionally and noninvasively. Arterial oxygen saturation (SaO2) is the measuring result out of pulse oximetry which technic we have discussed here above in the section of heart rate. Tissue saturation at peripheral scale can be measured using NIRS. The percentage that will be shown on the display mostly shows the ratio of oxy-haemoglobin in comparison with the total haemoglobin present in blood.

6.5. NON-CONVENTIONAL

6.5.1. Smart sensors

Introduction

Definition:

A smart sensor is a device that takes input from the physical environment and uses built-in compute resources to perform predefined functions upon detection of specific input and then process data before passing it on.

Smart sensors enable more accurate and automated collection of environmental data with less erroneous noise amongst the accurately recorded information. These devices are used for monitoring and control mechanisms in a wide variety of environments including smart grids, battlefield reconnaissance, exploration and a great number of science applications.

Our Viewpoint

Smart sensors are mostly described as sensors which are reacting in a certain way on gaining an input. Like in example a sensor that measures heart rate and from the moment it’s an abnormal measure which it gets, it will mostly send a warning. However since then basically anything that has at least one sensor and one microprocessor/microcontroller in its system can be called a smart sensor.

Reasoning

We took an interest into this category for our project mostly for a simple reason: if it has the sensors we need and there is a microcontroller we can reprogram it based on our needs. Since we are working with children safety and recognizable structures are key points. Our idea was then to use an object that the kids already know (like a wristband) and use it as a sensing tool. If we look further into this we need to make sure that the attention of the child is focused on something different while the nurse can take the measurements she needs from a distance without them even noticing it. In this perspective something small is a plus, because as we mentioned above the sensors itself are not that big and noticeable but when we build a circuit to interconnect them and build in a microcontroller it rapidity increases in format.

When looking at the technics we could use we found many flaws especially in the facts that for most of the measurements it really is important that the children feel safe and do not move too much. Which is mostly problematic, like we were brain storming about how we could weigh the child while it was driving in a toy car, the best possibility on reliable measurement we had was building the scale under the feet of the car so that the whole car is measured. If we would place the scale under the seat, from the moment the child moves more to the searing wheel its weight would decrease on the seat, and we wouldn’t able to have a reliable measurement. We are countering this exact problem with the smart sensor with a simple idea. The wrist band can do its measurements during movement and at any time, so if we design a game in which the kid need to stay on one spot for a certain time to activate the game we can measure the weight without him even noticing that he is on a scale. There are many of our problems that we discovered that we could solve using this system.

From another point of view this is a broad spectre solution which can be used in a lot of situations and not only for this case. It is innovative something that fits well with the image of this amazing hospital. There are a lot of ways in which nurses and doctors deal with this kind of problems, this is just another way. And one that is a bit more futuristic, with a lot of possibilities. This is exactly why we opted for this option and started our design around this idea.

Wearable's in healthcare

Intelligent Asthma management by health care originals

This product is currently in the design and production phase but there has been some up to date information that has been given out about it. What *Intelligent Asthma Management* by Health Care Originals does is present the consumer with what they call an Automated Device for Asthma Monitoring and Management or *ADAMM*. The device has a companion app that allows for a person to be able to get real time data when it comes to monitoring asthma. The device and the app will be able to alert you when you experiencing an asthma situation, journaling, treatment plans, displays, and the tracking and information on the treating of symptoms. [28]

Valedo Back Therapy

Valedo is engineered for those who have problems with lower back health. It has video game like interactions and interface that give the user exercises to do. It is very similar to like the games that you would see on a home video gaming system such as the *Wii* and *Wii Fit*. A device is attached to the person's back and the smart sensors are able to store data which can then be accessed through the companion app. It is run on *Bluetooth Smart* technology but at the current time can only be run on any *iOS* device such as an *iPad* or *iPhone*. [29]

HealthPatch MD

The *HealthPatch MD* is a new technology for healthcare professionals to be able to keep tabs on the vital information of their patients. The company behind this product is called *Vital Connect*. The *HealthPatch MD* is a biosensor that is reusable and it is embedded in a patch that can be disposed of. It has ECG electrodes and also has a 3 axis accelerometer that helps with keeping track of heart rate, breathing, temperature, steps, and even detects body position in case if a person has fallen. The *HealthPatch MD* is *Bluetooth* capable and could be connected to any mobile device in order to look at real time data received through the biosensor. [30]

Quell Relief

The product here by *Quell Relief* is one of the new healthcare wearable's and smart technology who really take functionality to the utmost. Not only is this *knee brace* type device engineered to give you the stability that you expect out of a brace but it is also embedded with the market required sensors that allow for smart keeping of information that can be accessed through a companion app. This product likes to pride itself on being able to give the person the optimal relief when it comes to a *knee brace*. [31]

Google Smart Contact Lenses

Google has been able to see itself in just about every other part of technology these days so why not the smart wearable's for healthcare market. *Google* has been able to have smart contact lenses that are made for people who suffer from diabetes and those who simply wear glasses. *Google* has partnered with the Swiss based pharmaceutical company in Novartis.

The technology is engineered to take the tears in a person's eye and measure the glucose levels that are present. For people who wear glasses, the lens would be engineered to what the companies say is 'to restore the eye's natural autofocus'. [32]

Abbott Diabetes Care

Abbott Diabetes Care is a company that is looking to venture into the smart wearables in healthcare industry. They recently received a *CE Mark* for *the FreeStyle Libre System* which is a new state of the art glucose monitoring system for people who suffer from diabetes. It is a sensor that is placed on the back of the upper arm for 14 days which reads glucose information. It eliminates the need for the finger prick system that everyone is so used to when it comes to glucose testing.

It is a companion app and smartphone accessible product where then a doctor can read over the information when the patient goes to the doctor. The app will also give information to people about the foods they should be eating and how to help control their diabetes through exercise and proper dieting. [33]

Leaf Healthcare Ulcer Sensor

Ulcer is something that affects everyone just about as they get older. Scientists believe that inactivity and constant sitting can also be one of the reasons of causing ulcers. The *Leaf Healthcare Sensor* is designed to alert a person when it is time to turn and do some moving in order to combat no moving around. The tri-axial accelerometer that is in the sensor can monitor the position that a person is in and then help assist them in proper ways to turn. It even works with optimizing tissue pressurization during turning and moving around.

The ulcers that the company is concerned with here are hospital ulcers which are common in assisted living facilities and nursing homes. When the monitor is put on a patient, the caregiver or physician will be given an alert if the person is moving around wrong or if they may need some assistance in moving the proper way. [34]

Comparison

Smart Sensors	Measuring data:	Place :	Protocol:	Price:

 **Figure 23: FitBit**	measures: HR	wrist	wireless connection: Bluetooth Low Energy	120$
 **Figure 24: Microsoft Band**	activity sensor	wrist	wireless connection	150$
 **Figure 25: Withings**	measure: HR, SpO separate devices		wireless connection: Bluetooth dedicated for Android, iOS	90$
 **Figure 26: Nymi**	measures ECG	wrist	dedicated for Android, Mac, Windows	130$
 **Figure 27: ADAMM**	cough rate, respiration patterns, heartbeat, temperature	Above the heart	Android and windows	Not yet on market
 **Figure 28: Valedo® - Digital Back Therapy**	3D gyroscope 3Daccelerometer 3D magnetometer	back	iPad 3rd generation and higher, all iPad mini, iPhone 5th generation and higher, Android 4.4 and higher with Bluetooth Low Energy Technology	299 euro

 **Figure 29: Heathpad MD**	Single-Lead ECG, Heart Rate, RR Interval, Heart Rate Variability, Respiratory Rate, Skin Temperature, Body Posture, Fall Detection, Activity including Steps	Close to heart	Bluetooth low energy connectivity, Wi-Fi connection and other data relay's	
 **Figure 30: Freestyle precision pro system**	blood glucose and β-ketone	blood	802.11a, 802.11b, 802.11g	
 **Figure 31: The leaf wireless**	Turning of patients	Chest	wireless mesh network	
 **Figure 32: Angel sensor**	HR, SpO, skin temperature	wrist	wireless connection: Bluetooth SMART dedicated for Android, iOS	90$

Table 4: Comparison Smart sensors

Conclusion

We chose the *Angel sensor* based on the fact that it measures most vital signs we need, and it would be easy to access the data from it with our application by *Bluetooth sma*rt connection between the tablet and the wrist band. This sensor is also reprogrammable to our needs which is another big plus of this accessory. It is a simple wristband which children will recognize as an accessory, which means that they would be less anxious wearing it.

6.5.2. Communication

During the development of any technological product it is really important to find the appropriate way to transfer the information that this could provide or need to function properly.

In the market there is a wide variety of communication options such as *Wi-Fi, Bluetooth, infrared* among the wireless connections and usb cable using wire connection. Which is the best option? The wireless connection fits best with the requirements of this project, although the wire connection is more reliable the advantages of a wireless connection are crucial to make this system work.

The appropriate communication system leads to the discussion of the pros and cons between *Wi-Fi* and *Bluetooth*. Basically everything that includes a *Wi-Fi* communication requires the hardware configuration of a physical receiver, router, while *Bluetooth* does not.

Wi-Fi, which originally meant "*wireless fidelity*," is primarily about connecting one or many devices to the Internet, or creating a local wireless network that can link multiple devices. It depends on a central base station (or multiple stations) that sends out a network signal strong enough and wide enough to cover, say, an office or home, a coffee shop or even an airport.

Bluetooth is much shorter-range, usually around 10 meters. It rarely involves getting onto the Internet, and doesn't depend on any central device like a router. It is almost always used to connect two devices together in some useful way.

What is Bluetooth?

Bluetooth is a global wireless communication standard that connects devices together over a certain distance. Think about a headset and a phone, a speaker and a PC and more. It is built into billions of products on the market today.

What makes Bluetooth better than other technologies?

Bluetooth is everywhere, it operates on low power, it is easy to use and it doesn't cost a lot to use:

- ~ *Bluetooth* is everywhere—you will find *Bluetooth* built into nearly every phone, laptop, desktop and tablet. This makes it so convenient to connect the wristband to the tablet using the *android* app.
- ~ *Bluetooth* is low power—with the advent of *Bluetooth Smart (BLE or Bluetooth low energy*), developers were able to create smaller sensors that run off tiny coin-cell batteries for months, and in some cases, years.
- ~ *Bluetooth* is easy to use—for consumers, it really can't get any easier. You go to settings, turn on your *Bluetooth*, hit the pairing button and wait for it start communicating. That's it. From a development standpoint, creating a Bluetooth product starts with the core specification and then you layer profiles and services onto it.
- ~ *Bluetooth* is low cost—you can add *Bluetooth* for a minimal cost. You will need to buy a *module/system on chip* (*SoC*).

7. Proposed Solution

7.1. OVERVIEW

7.1.1. Sketch

Figure 33: Nurse taking results

Figure 34: Child playing our game

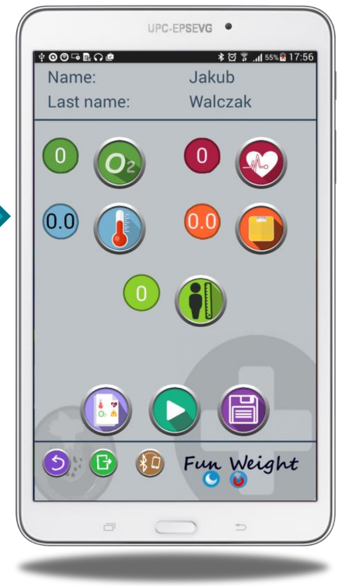


Figure 35: Our application on patient screen

7.2. REQUIREMENT ANALYSIS

7.2.1. Anthropometric

What is anthropometry?

Anthropometry is the science that defines physical measures of a person´s size, form and functional capacities. As applied to occupational injury prevention, anthropometric measurements are used to evaluate the interaction of workers with tasks, tools, vehicles and personal protective equipment, especially in regard to determining degree of protection afforded against hazardous exposures, whether chronic or acute. [35]

The use of anthropometric measurements is a well-established practice for many clinical purposes including screening and health risk assessment. This is particularly useful in pediatric population as these measurements can be used to track growth rate and identify abnormal growth trends.

Importance of Anthropometrics

Our design has to show consideration of the young patients that we are designing for. We will then have a final product that fits properly, is more comfortable to use and effective in its actions. Much of the information that has allowed an effective design to be created has been found out from our study of anthropometrics.

Data collection

The anthropometric data which are included in the following tables are referred to U.S. children in a period from 1988 to 1994. The data are from the Third National Health and Nutrition Examination Survey (NHANES III), which has conducted on a complex, stratified, multistage probability sample of the civilian U.S population. The reasoning for using those data is that NHANES is a trustful organisation who also includes a wide and detailed collection of anthropometrics which are needed in this case. Taking into account the age range that it has been settled from Sant Joan de Deu Hospital, in the following tables it will be presented the main anthropological characteristics which are needed for the Fun Weight project.

Sex and age [years]	Number of examined people	Mean [kg]	Standard error of the mean [kg]
Male			
3	516	15.8	0.20
4	549	17.7	0.18
5	497	20.1	0.25
6	283	23.3	0.57
7	269	26.3	0.56
8	266	30.2	0.83
9	281	34.4	0.87
10	297	37.3	0.87
Female			
3	587	15.4	0.16
4	537	17.9	0.27
5	554	20.2	0.27
6	272	22.6	0.55
7	274	26.4	0.69
8	248	29.9	0.80
9	280	34.4	1.03

10	259	37.9	1.05

Table 5: Weight in kilograms for children aged 3 to 10 years old and number of examined people, mean standard error, by sex and age. United States 1988-1994

Sex and age [years]	Number of examined people	Mean [BMI]	Standard error of the mean [BMI]
Male			
3	512	16.1	0.16
4	547	15.9	0.10
5	495	15.9	0.13
6	282	16.3	0.26
7	269	16.5	0.24
8	266	17.3	0.34
9	279	18.0	0.33
10	297	18.4	0.30
Female			
3	583	15.9	0.14
4	533	16.0	0.21
5	554	15.9	0.27
6	272	16.1	0.32
7	274	16.9	0.35
8	247	17.3	0.42
9	280	18.2	0.47
10	258	18.4	0.46

Table 6: Body mass index for children aged 3 to 10 years old and number of examined children, mean and standard error, by sex and age. United States, 1988-1994

Sex and age [years]	Number of examined people	Mean [cm]	Standard error of the mean [cm]
Male			
3	513	98.8	0.32
4	551	105.2	0.33
5	497	112.3	0.38

6	283	118.9	0.65
7	270	125.9	0.68
8	269	131.3	0.60
9	280	137.7	0.65
10	297	142.0	0.83
Female			
3	590	98.2	0.33
4	535	105.1	0.36
5	557	112.2	0.41
6	274	117.9	0.61
7	275	124.3	0.67
8	247	131.1	0.70
9	282	136.6	0.70
10	262	142.7	0.74

Table 7: Height in centimetres for children aged from 3 to 10 years old and number of examined children, mean and standard error by sex and age. United States: 1988-1994

Sex and age [years]	Number of examined people	Mean [cm]	Standard error of the mean [cm]
Male			
3	495	50.3	0.10
4	549	50.8	0.10
5	491	51.5	0.10
6	275	52.0	0.16
7	261	52.5	0.14
Female			
3	574	49.5	0.07
4	528	49.9	0.08
5	553	50.7	0.08
6	269	51.0	0.11
7	267	51.3	0.13

Table 8: Head circumference in centimetres for children aged 3 to 7 years old and number of examined children, mean and standard error, by age and sex. United States 1988-1994

Sex and age [years]	Number of examined people	Mean [cm]	Standard error of the mean [cm]
Male			
3	487	3.8	0.02
4	544	3.9	0.02
5	495	4.1	0.02
6	279	4.2	0.03
7	269	4.4	0.03
8	261	4.5	0.04
9	276	4.7	0.03
10	294	4.8	0.03
Female			
3	567	3.6	0.02
4	528	3.8	0.02
5	555	3.9	0.02
6	274	4.1	0.03
7	269	4.2	0.04
8	245	4.4	0.03
9	271	4.6	0.03
10	257	4.7	0.04

Table 9: Wrist breadth in centimetres for children aged three to ten years old and number of examined children, mean, standard of error by age and sex. United States 1988-1994

All data can be found at: www.cdc.gov/nchs7data7series7sr_11/sr11_249.pdf

7.2.2. Restrictions

Functional requirements:

- creating database containing patients' and measurements' data
- mobile application dedicated for tablets with Android OS that will communicate with the device
- mobile application should have buttons enabling performing particular measurements
- mobile application should show taken measures

- mobile application should have field for comments concerning measurement
- dashboard of the toy should provide some information for kids
- toy could use light and sound effects
- Software has to have ability to connect to database and perform operation of retrieving patients, adding patients and getting measurements for a particular patient
- Database should be accessible from different devices and cannot occupy memory of a device
- Connection to database should be realized via Internet
- Connection with system hardware should be realized using Bluetooth standard
- Application has to enable preview of all patient and deep investigation of chosen one

Non-functional requirements:

- The toy should be interesting for all of kids
- The toy should be safe even without nurse supervision
- The toy should be easy and convenient to use by all staff
- The interface should be intuitive and easy to use for non- technical staff

Accuracy

- measuring heart rate, temperature, oxygen level with accuracy at the level of +/-0.1 of unit
- measuring weight with accuracy of order +/-0.5kg

7.2.3. Context of use

Physical scenario:

Right now we hope to be able to place our device in the waiting room that is similar to the rainbow room.

The envoirment is child friendly and doesn’t increase anxiety of a child.

It is a colourful room with a lot of light entering, the toys which they can use are also placed there.

The child is not alone but with parents, nurse (when needed) and other children.

Presurgery treatment:

- Presurgery treatment. Performing essential measurements for surgery.
- A nurse switches on the device
- The sensors are applied to a kid
- The nurse runs the Android application
    - a. The nurse chooses a patient from database
    - b. The nurse adds a patient to database
- The nurse chooses necessary vital sign(s) which are needed to be measured on the tablet, tapping the an appropriate button(s)
- Measurements are being taken while a patient is occupied by a calm entertaining game

- ~ Results are displayed on the tablet screen and stored in the database
- ~ The nurse disconnect a patient from the device

Social environment:

The environment plays a significant role in the psychological aspect of hospital treatment especially during long hospitalization. Presence or absence of parents is one of the factors posing crucial impact on kid's behaviour. In terms of vital signs measurements it might turn out either as a positive or a negative factor. Positive if it makes kid calm and peaceful, but on the other hand in might make a kid hyperactive or too excited. The latter decreases reliability of taken measurements. On the basis of gathered knowledge it is obvious that parents should be present during kid's hospitalization, but not during taking measurements. Simultaneously, the device should be designed so that it interests kid. Nevertheless, awareness that parents are waiting outside should be preserved.

Until now, hospital uses conventional ways of pacifying kids in pre-surgery treatment. It is realized mainly by colourful rooms full of toys. Moreover, it becomes more and more popular using new technologies in order to improve kid's wellbeing during hospitalization. In Great Ormond Street Hospital in London human-size robot enable sick kids to visit the zoo by virtual reality. Another example is Michigan's C.S. Mott Children's Hospital where Gear VR is used to prevent loneliness during hospitalization

Functions/uses:

- ~ taking measurements of skin temperature, oxygen saturation, heart rate and weight
- ~ providing entertainment for a patient in order to avoid patients anxiety

Target user profile

Age:	3-10 years old
Gender:	Female/Male
Preferences:	-
Capabilities/Impairments:	allowed for disabled kids

System

Technical description:

The system is supposed to perform operations indicated in section 7.1.1.1 Restrictions. In functional requirements. An application will be dedicated for tablets powered by Android OS. Android Studio has been chosen as an Integrated Development Environment for developing the application. Tests will be performed on real device- Samsung SM- T230.

Interfaces:

- Angel Sensor SDK
- Apache HTTP API
- Android Bluetooth API

Functionalities:

- connecting to database
- checking list of existing patients
- checking a history of measurements for a particular patient
- addition of a new patient to database
- performing measures for existing patient (patient has to be present in database)
- addition comments to taking measurements

8. Smart Wristband

8.1. INTRODUCTION

We chose a smart sensor which is developed by company the *Angel Sensor*, we used it for our developed application. Mainly to use the provided sensors to perform the measurements.

Figure 36: Angel sensor logo

Angel Sensor is an open wearable for developers who are building new mobile health products. *Angel Sensor* tracks the heart rate, skin temperature, steps, acceleration, and orientation. It offers unrestricted, real-time *API*[1] to its sensors and full control of the data. *Angel Sensor SDKs*[2], *Bluetooth* profiles and apps are open source. The *SDKs* support *iOS* and *Android*.

Figure 37: Angel Senor Wristband

[1] Application program interface (API) is a set of routines, protocols, and tools for building software applications. An API specifies how software components should interact and APIs are used when programming graphical user interface (GUI) components. A good API makes it easier to develop a program by providing all the building blocks.

[2] Short for software development kit, a programming package that enables a programmer to develop applications for a specific platform. Typically an SDK includes one or more APIs, programming tools, and documentation.

8.2. DESIGN, TECHNICAL SPECIFICATIONS AND NORMS

8.2.1. Smart Wristband

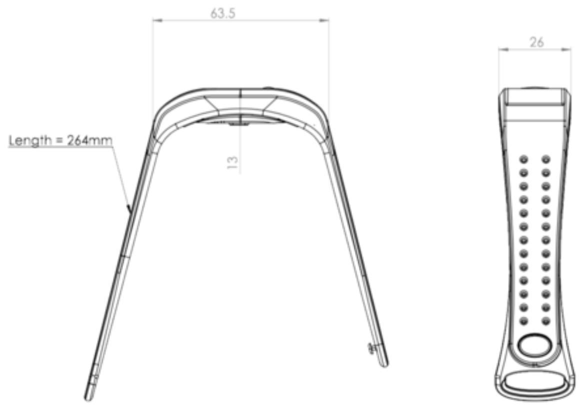


Figure 38: Schematic of the Angel sensor wristband

Dimensions: 264mm x 26mm x 13mm

Weight: 29g

Battery life: up to 7 days, based on sensor use.

8.2.2. Technical specifications

A total of 28, 8 grams it is the weight of the smart band which contains all the listed components on the following chart:

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	Energy (MJ)	%
Wristband	Silicone (VMQ, heat cured, 10 -30% fumed silica)	Virgin (0%)	0,013	1	0,013	1,5	14,2
Body	ABS+PA (unfilled)	Virgin (0%)	0,01	1	0,01	1,2	11,2
Pins (wristband)	ABS+PA (unfilled)	Virgin (0%)	0,0002 5	2	0,0005	0,061	0,6
Battery	Li-Ion AA cell battery	Virgin (0%)	0,0018	1	0,0018	0,36	3,3
Leds	Diodes and LEDs	Virgin (0%)	0,0002 5	2	0,0005	2,3	21,4
Others (integrated circuit)	Integrated circuit (small)	Virgin (0%)	0,003	1	0,003	5,4	49,3
Total				**8**	**0,028**	**11**	**100**

Figure 39: Technical specification of the Angel Sensor wristband

8.2.3. Energy and power

Figure 40: Lithium polymer battery

The specification of self-timer's battery (60mah lithium battery PL451020-60mAh):

~ Lithium polymer battery PL451020-60mAh has long cycle life, low resistance, light weight, enough capacity.
~ This lithium battery can discharging at 2C
~ 60 mAh battery is suitable for *self-timer*, *Bluetooth*, wireless mouse.
~ The thickness of lithium polymer battery can be adjusted while the length and width remain the same as before.
~ *CE, SGS* certificates.
~ Produce goods on time and quality assurance.

1	Capacity	60mAh
2	Voltage	3.7V
3	Dimensions (mm)	≤4.5(T) * ≤10.5(W) *≤20.5(L) (mm)
4	Weight (g)	1.8g
5	Max. charge voltage	4.2V
6	Max. charge current	1CmA
7	Min. discharge voltage	2.75V
8	Max discharge current	1CmA
9	Charge temperature	0ºC ~ + 45ºC
10	Discharge temperature	-20ºC ~ + 60ºC
11	Storage humidity	≤ 75%

Table 10: Technical speciation of lithium battery

8.2.4. Communication

RFID / NFC

Angel Sensor ships with on board RFID/NFC Forum Type 2 Tag with writable memory.

Figure 41: NFC FORUM TYPE 2 TAG

NFC Forum Type 2 Tag is based on ISO 14443-A standard. Tags are read and re-write capable. Users can configure the tag to become read-only. Memory availability is 48 bytes and expandable to 2 Kbyte. Communication speed is 106 Kbit/s.

Standard: ISO 14443-A

Chip: *Mifare Ultralight* (NXP)

Mifare Ultralight has been commercially available for long time. It has been used in several *RFID* and mobile RFID/NFC solutions. The tag type has real-life tested to be reliable, suitable for several purposes and also cost-efficient.

8.2.5. Normative

IP67

IP stands for 'Ingress Protection'

An IP number is used to specify the environmental protection of enclosures around electronic equipment. These ratings are determined by specific tests.

The IP number is composed of two numbers, the first referring to the protection against solid objects and the second against liquids. The higher the number, the better the protection.

First Number

0 - No protection (Sometimes X)

1 - Protected against solid objects up to 50mm^3

2 - Protected against solid objects up to 12mm^3

3	- Protected against solid objects up to 2.5mm³
4	- Protected against solid objects up to 1mm³
5	- Protected against dust, limited ingress (no harmful deposit)
6	- Totally protected against dust

Table 11: First number of IP number

Second Number

0	- No protection (Sometimes X)
1	- Protection against vertically falling drops of water (e.g. condensation)
2	- Protection against direct sprays of water up to 15 degrees from vertical
3	- Protection against direct sprays of water up to 60 degrees from vertical
4	- Protection against water sprayed from all directions - limited ingress permitted
5	- Protected against low pressure jets of water from all directions - limited ingress permitted
6	- Protected against low pressure jets of water, limited ingress permitted (e.g. ship deck)
7	- Protected against the effect of immersion between 15cm and 1m
8	- Protected against long periods of immersion under pressure

Table 12: Second Number of IP number

8.3. MEASUREMENT SENSORS

8.3.1. Temperature

The skin is the largest organ in the human body. It protects the body from the sun's rays. It also keeps body temperature normal (37 °C).

Skin temperature depends on air temperature and time spent in that environment. Such weather factors as wind chill and humidity cause changes in skin temperature. The normal temperature of skin is about 33 °C or 91 °F [36].

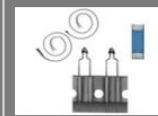
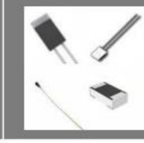
Criteria	Temp Sense IC 	Thermistor 	RTD 	Thermocouple 	IR Temp Sensor 
Temp Range	-55°C to +150°C	-100°C to +500°C	-240°C to 700°C	-267°C to +2316°C	-100°C to +500°C
Accuracy	Meets requirements	**Depends on calibration**	Meets requirements	**Depends on cold junction compensation**	**Depends on calibration**
Linearity	Best	Least	Better	Better	Better
Sensitivity	Better	Best	Less	Least	Less
Circuit Simplicity	Simplest	Simpler	Complex	Complex	Simple to Complex
Power	Lowest	Low	High	High	Medium
Cost	$	$-$$$	$$$	$$	$$

Figure 42: Comparing table with the most common temperature sensors

Since there is a shortage about the technical details of the *Angel Sensor* we compared the most used 'built in' temperature sensors. We assume based on our results from the wristband that the IC's are the sensors which were used in this wristband to sense the skin temperature.

Figure 43: LMT70

The LMT70 is an analog output temperature sensor that has 0.05°C typical accuracy within the human body temperature range (20°C-42°C). The LMT70 comes in a tiny chip scale WLCSP package that measures just 0.88mm x 0.88mm which makes it ideal for space conscious designs. The part's wide voltage range of 2V-5.5V and low 12uA current consumption allows it to be paired with a variety of batteries common in portable electronics. With these specs, the LMT70 is TI's smallest, most accurate temperature sensor and is perfect for applications where high thermal accuracy is required and PCB board space is limited.

8.3.2. Heart rate

The wristband we use to gather data that we need, uses the next explained way to 'sense' the heart rate.

The skin is so richly perfused so it is relatively easy to detect the pulsatile component of the cardiac cycle.

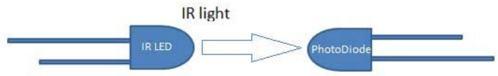


Figure 44: infrared led and photodiode

The change in volume caused by the pressure pulse is detected by illuminating the skin with the light from a light-emitting diode (LED) and then measuring the amount of light either transmitted or reflected to a photodiode.

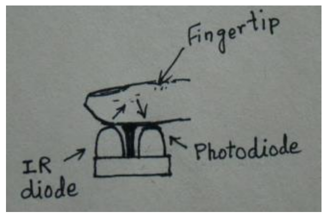


Figure 45: Working of IR- and Photodiode

8.3.3. Oxygen saturation

The wristband we use to gather data that we need, uses the next explained way to 'sense' the oxygen saturation.

A **photoplethysmogram** (**PPG**) is an optically obtained plethysmogram, a volumetric measurement of an organ. A PPG is often obtained by using a pulse oximeter (Pulse oximetry is a non-invasive method for monitoring a person's oxygen saturation (SO_2)) which illuminates the skin and measures changes in light absorption[3]. A conventional pulse oximeter monitors the perfusion of blood to the dermis and subcutaneous tissue of the skin.

Because blood flow to the skin can be modulated by multiple other physiological systems, the PPG can also be used to monitor breathing and other circulatory conditions[4].Additionally, the shape of the PPG waveform differs from subject to subject, and varies with the location and manner in which the pulse oximeter is attached.

d) OPTICAL WAVEFORM (PPG)

Here we can see an example of the dual waveforms obtained during the pulse oximeter measurement.

Source	Dual wavelength reflection photoplethysmography

[3] K. Shelley and S. Shelley, *Pulse Oximeter Waveform: Photoelectric Plethysmography, in, in*, in Clinical Monitoring, Carol Lake, R. Hines, and C. Blitt, Eds.: W.B. Saunders Company, 2001, pp. 420-428.

[4] A. T. Reisner, P. A. Shaltis, D. McCombie, and H. H. Asada, Utility of the Photoplethysmogram in Circulatory Monitoring, Anesthesiology, vol. 108, pp. 950-958, 2008.

Column order	LED1 (green), LED2 (blue)
Sampling rate	100 Hz
Format	24 bits, signed
Filtering	None

Table 13: Summary of the properties on the PPG test

A pulse oximeter is essentially two photoplethysmography (two different wavelengths of light: nm values). Oxygenated blood and deoxygenated blood each absorb at different wavelengths. The difference between the two waveforms indicates the ratio of oxygenated to deoxygenated blood.

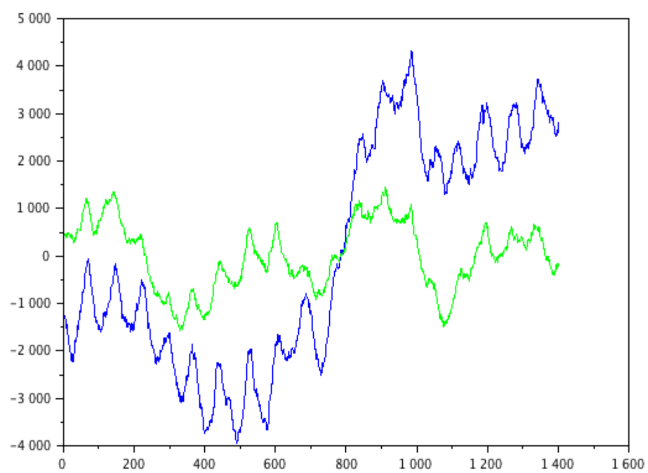


*Figure 46: Dual Waveform, oximeter pulse (nm / Time (m*10-3 seconds))*

8.3.4. Communication

The primal communication system is *Bluetooth SMART*.

e) What is Bluetooth SMART?

Bluetooth low energy (Bluetooth LE, BLE, marketed as Bluetooth Smart) is a wireless personal area network technology designed and marketed by the *Bluetooth Special Interest Group* aimed at novel applications in the healthcare, fitness, beacons, security, and home entertainment industries.

The Smart Wristband works with *Android* smartphones, requires *Bluetooth SMART*. More information is provided in the Appendix A, about *Bluetooth SMART*.

8.4. ECO-DESIGN

The application *Eco-audit tool* it is applied to enhance the effectiveness of energy consumption and material characteristics of the smart wristband *Angel Sensor*. While introducing to life-cycle thinking the following report shows how eco-friendly *Angel Sensor* is.

What is *EoL* (End of Life) potential?

End-of-life potential: the energy or CO_2 savings or 'credits' that can be realized in future life cycles by using the recovered material and thus avoiding the use of virgin material. This is a net value, and takes into account the energy costs and CO_2 footprint of the end-of-life process itself (for instance, the CO_2 released during combustion).

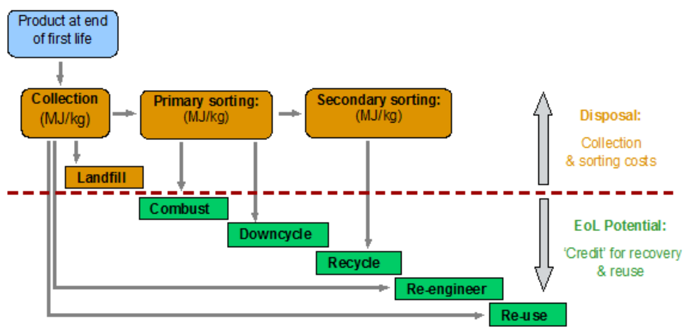


Figure 47: Disposal vs EoL Potential

End-of-life potential calculations for Recycle

The energy costs and CO_2 footprint of the recycling process are offset by the saving of the energy and CO_2 that would otherwise have been associated with the production of virgin raw material.

It is assumed that 100% of the material is recovered for recycling, therefore:

$$Energy_{end\text{-}of\text{-}life\ potential} = (Energy_{recycling} - Energy_{production}) \times Mass$$

And

$$CO_{2\text{-}end\text{-}of\text{-}life\ potential} = (CO_{2\text{-}recycling} - CO_{2\text{-}production}) \times Mass)$$

Where:

$Energy_{recycling}$ = *Embodied energy, recycling* (MJ/kg) for the material

$Energy_{production}$ = *Embodied energy, primary production* (MJ/kg) for the material

$CO_{2\text{-}recycling}$ = *CO_2 footprint, recycling* (kg/kg) for the material

$CO_{2\text{-production}}$ = *CO_2 footprint, primary production* (kg/kg) for the material

Mass = mass of part

For materials that are commonly recycled, such as metals and glasses, the energy usage and CO_2 footprint associated with recycling the material are typically much lower than the energy usage and CO_2 footprint associated with production of virgin raw material, so the end-of-life potential values are likely to be negative

In order to determine whether the smart band is sustainable or not the study is based considering five years of the lifetime of the product. After proceeding with the study with the eco audit tool in the following graphs is demonstrated that the environmental impact is noticed the most on to the materials. The main reason is that this device has a very low power consumption while using a small battery and low power Bluetooth connection.

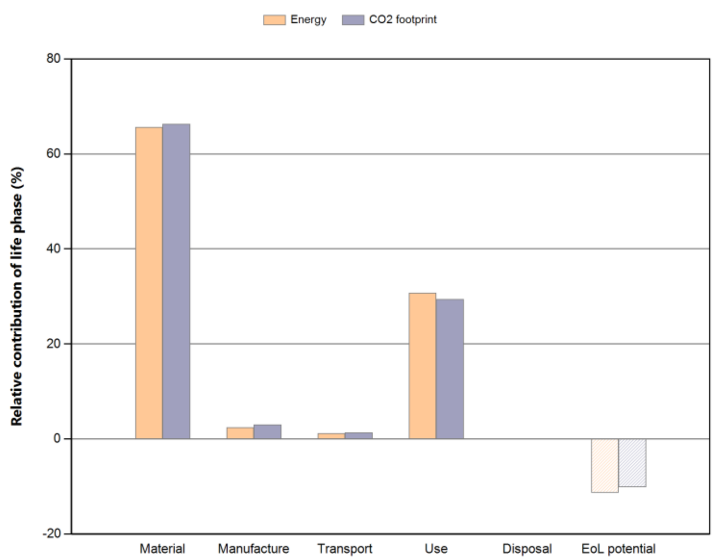


Figure 48: Relative contribution of life phase %. Energy - CO2 footprint

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Material	10,9	65,6	0,69	66,3
Manufacture	0,406	2,5	0,0314	3,0
Transport	0,192	1,2	0,0137	1,3
Use	5,09	30,7	0,306	29,4
Disposal	0,00566	0,0	0,000396	0,0
Total (for first life)	**16,6**	**100**	**1,04**	**100**

End of life potential	-1,87		-0,106	

Table 14: Summary of phases of Energy and CO2 footprint

The end of life potential has its most impact by recycling the main parts of the smart band: the body and the wristband (It is noticed by the yellow color in the graphs).

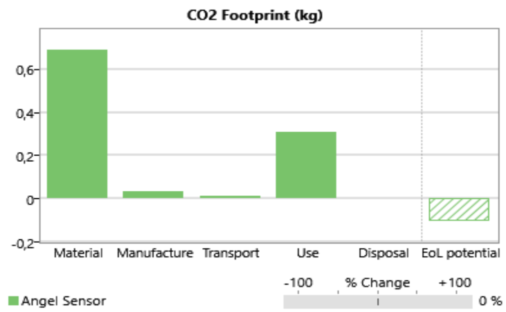


Figure 49: CO2 Footprint of Angel sensor

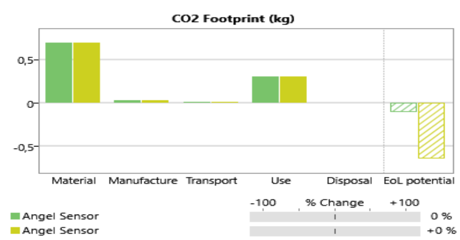


Figure 50: CO2 Footprint of Angel sensor (body and wristband)

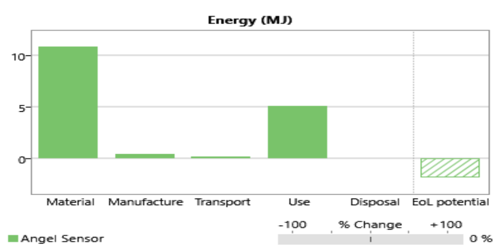


Figure 51: energy use of Angel sensor

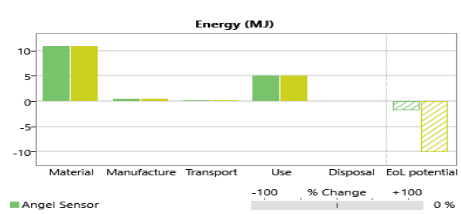


Figure 52: energy use of Angel sensor (body and Wristband)

8.4.1. Improvements

In the next tables and graphs demonstrate by changing the recycled content on the ABS polymers (Body and pins) the improvement on its environmental performance.

Components

Qty.	Component name	Material	Recycled content	Mass (kg)	Primary process	Secondary process	% removed	End of life	% recovered
1	Wristband	Silicone (VMQ, heat cur	Virgin (0%)	0,0125	Polymer molding		0	Re-manufacture	100
1	Body	ABS+PA (unfilled)	Virgin (0%)	0,01	Polymer molding		0	Landfill	100
2	Pins (wristband)	ABS+PA (unfilled)	Virgin (0%)	0,00025	Polymer extrusion		0	Landfill	100
1	Battery	Li-Ion AA cell battery	Virgin (0%)	0,0018	Incl. in material value		0	Reuse	100
2	Leds	Diodes and LEDs	Virgin (0%)	0,00025	Incl. in material value		0	Landfill	100
1	Others (integrated circuit)	Integrated circuit (smal	Virgin (0%)	0,003	Incl. in material value		0	Landfill	100

Figure 53: Table of components during the first step of the study

Components

Qty.	Component name	Material	Recycled content	Mass (kg)	Primary process	Secondary process	% removed	End of life	% recovered
1	Wristband	Silicone (VMQ, heat cur	Virgin (0%)	0,0125	Polymer molding		0	Reuse	100
1	Body	ABS+PA (unfilled)	80,0%	0,01	Polymer molding		0	Recycle	100
2	Pins (wristband)	ABS+PA (unfilled)	80,0%	0,00025	Polymer extrusion		0	Recycle	100
1	Battery	Li-Ion AA cell battery	Virgin (0%)	0,0018	Incl. in material value		0	Downcycle	100
2	Leds	Diodes and LEDs	Virgin (0%)	0,00025	Incl. in material value		0	Reuse	100
1	Others (integrated circuit)	Integrated circuit (smal	Virgin (0%)	0,003	Incl. in material value		0	Reuse	100

Figure 54: Table of components with the proper changes of recycled content and end of life performance

After proceeding the changes it is noticed the improvement mainly on the EoL potential and the material Energy cost and CO2 Footprint. There is a 4% less energy consumption and 3% less CO2 Footprint.

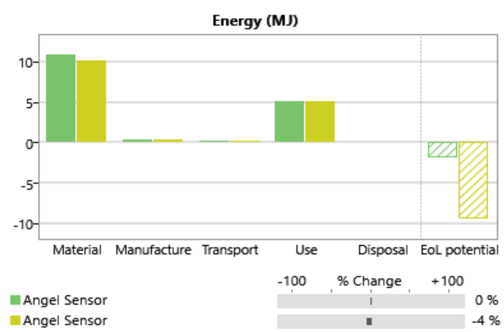


Figure 55: energy use of Angel sensor after introduced changes in materials

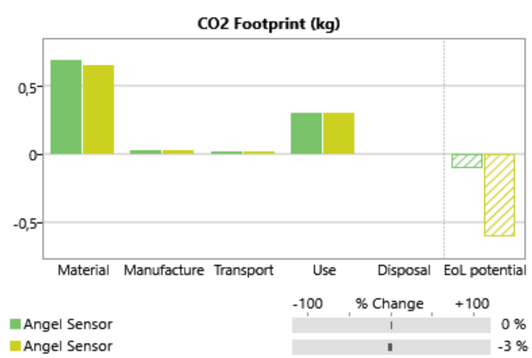


Figure 56: C02 Footprint of Angel sensor after introduced changes

9. Application and interface development

9.1. INTRODUCTION

As in all existing systems, also in the project described in this paper, communication with a user poses essential aspect of a non-fully autonomous device. Nowadays it is realized in many cases by a specific application integrated with the hardware of the system to enable easy and comfortable interface with the complete system. An application that is supposed to be delivered for this project has to be designed taking into consideration plenty of requirements that in details are listed in 7.2.3 Restrictions.

In order to provide more flexibility and scalability of the system, the mobile application has been designed in the way that enables cooperation with different measuring smart bands as long as they fulfil Bluetooth Low Energy[5] standard. It should be noticed that use of other measuring devices, except recommended in this paper, might result in limited functionality- for details, see Appendix A.

9.2. DESIGN

In order to design an application suitable for a target user (nurses) and intuitive, Human Cantered Design approach has been applied. Thus, interaction with the user has been emphasized, simultaneously caring about functionality of the system. This approach consists of the two stages: recognition of user interface design strategies and applying these strategies into the application.

Foundation of our consideration was basic colour scheme of the mobile application. As Thomas Cannon states in [36] , the most readable combination of colours is using very light tint of background and dark one for the font, especially when the user is present in a well lit room [37] like a nurse. Moreover, according to the author of [37] application of inverted schemes is good solution for headings. Although good readability, provided mostly by high contrast, is crucial in all systems, it had to be balanced by other factors that need to be taken into consideration. While mix of black and white colour ensures the highest possible contrast, according to below formula [38](considering human eye reaction for different colours), it causes high eye strain [39]. To avoid it, grey combination should be used [39].

$$C = \frac{|(299R_F + 587G_F + 114B_F) - (299B_B + 587G_B + 114B_B)|}{1000}$$

Where: C- value of contrast; R, G and B are intensities of respectively Red, Green and Blue colour (values <0,255>); annotations F and B means values respectively for: Font and Background.

In the above formula values two hundred fifty five of contrast means the highest possible contrast, zero means the lowest contrast.

---

[5] Bluetooth Low Energy- is a technology of low power consuming generic communication. For details see Appendix A

On the basis of obtained information, appropriate colours of font and background has been chosen. Contrast comparison is presented in the Table 15.

Colour scheme description			Contrast value
Colour			**255**
Hexadecimal value	#000000	#FFFFFF	
Colour			**132**
Hexadecimal value	#34495E	#BEC3C7	

Table 15: Objective comparison of colour schemes

Although contrast ratio of applied scheme is virtually two times lower, according to conducted research its readability has been high estimated (for details see chapter Application> Tests).
In order to make the application intuitive for the user, especially non-technical ones, graphical interface was developed. It was proven in [40] that novice users require less time and less steps to perform operation using graphical interface instead of textual one. However, symbols often introduce ambiguity that is highly undesirable, particularly in medical systems. A solution for that issue was presented in [5] by Aurora Bedford who recommend using labels for icons for better performance. Also taking into consideration threads pointed out in [41] that flat icon used in an application require two times more time to identify them than realistic icon. There was adapted an unambiguous method of denoting buttons by applying realistic border.
So that fully intuitive and functional application can be provided, a number of usability heuristics listed below has been adopted [42].

- Ad. 1: Visibility of the system status
- Ad. 2: Match between system and real world
- Ad. 3: User control and freedom
- Ad. 4: Consistency and standards
- Ad. 5: Recognition rather than recall
- Ad. 6: Flexibility and efficiency of use
- Ad. 7: Aesthetic and minimalistic design
- Ad. 8: Help user recognize, diagnose and recover from errors
- Ad. 9: Help and documentation

Ad. 1. Visibility of the system status
This heuristics requires providing appropriate feedback for the user conform to current status of the system. In the application being described in the section, this heuristic is realized by displaying progress

bars for asynchronous activities time-consuming and displaying Toast[6] information about occurred events so that a user is aware about activities being processed in the system

Ad 2. Match between system and real world
This requirements expects system to use terms and language appropriate for a target audience. In order to satisfy this, research was conducted about applying proper for medical staff icons (for details see subsection Test).

Ad. 3. User control and freedom
The heuristic means providing control for the user over the system. It is realized by providing additional Back and Logout buttons for each view, that ease handling of the mobile application. Certainly control over the system is limited for a user, especially in terms of database transactions.

Ad. 4. Consistency and standards
The fourth heuristics assumes consistency of icons, style, terminology and others throughout the system as well as applying standards having application in the dedicated field. In the application it is realized by keeping consistent style convention over the application and using appropriate icons according to conducted research (see subsection Test).

Ad. 5. Recognition rather than recall
This one aims at providing easy recognizable layout elements and reducing necessity of remembering them by a user. For the application being subject of this part, the heuristic is satisfied by icons either unambiguous for a target user or by providing labels for these ones that can cause doubts.

Ad. 6. Flexibility and efficiency of use
The point of this heuristic is to allow both novice and expert users efficient use of the system. For expert users navigation shortcuts should be provided for the most frequent tasks. In terms of the mobile application it is the main goal of the future development. Until now the only shortcut is solely button enabling instantaneous log out from the application.

Ad. 7. Aesthetic and minimalistic design
The goal of this heuristic is to provide only essential information and elements and to prevent competition between visual design and more relevant data. In the application this heuristic is applied for all system views by providing as little information and icons as possible.

Ad. 8. Help user recognize, diagnose and recover from errors
The name of this heuristic speaks for itself. User should be explicitly notified about all undesired behaviour. In the application, information about errors or not matching formats during input of the data are presented in the form of Toast notifications in the bottom of the screen.

---

[6] Toast- is short information shown in the rounded rectangle in the bottom of the screen

Ad. 9. Help and Documentation

As the name suggest, this heuristic demands providing support for the user. Following this requirements, user guide has been created to enable users to get acquainted with the application (for User Guide see chapter 14. User guide).

Besides above heuristics, the results of prototype evaluation of [43]has been applied in the context of issues described below.

As a part of navigation issues, results obtained in [43] conform to Google Inc. suggestions [44]which states that navigation bar should be placed in the bottom of the screen to make it more accessible according to activity zones on tablet pointed out in [45].

Also conclusions concerning visual perceptions [43]has been adopted into the application design.

Sample of the software outlook, designed taking into consideration above guidelines, is presented in the Figure 57.

Figure 57: Design of the application

According to conducted tests of the user interface among non-technical participants, X per Y participants correctly understood meaning of particular application parts and their purpose.

An application icon was designed with use of Hospital Sant Joan de Deu logo. The final icon is presented in the Figure 58.

Figure 58: Application logo

9.3. DEVELOPMENT

Besides user interface, that is indispensable part of the software, backend of the application is crucial for satisfying functional requirements demanded from the complete system. As an approach to programming, Test Driven Development[7] methodology has been partially adopted. Due to the fact that application is dedicated for mobile devices and that patients data needs to be accessible from different devices, online database has to be adopted into the software. The detail information concerning database is included in subchapter B. Database.

As the database is not local[8], it constitutes a separate part of the system. Thus the necessity of dividing software into two parts appeared in order to fulfil all requirements. First part concerns handling of database using web service- it is described in part Web service, the second one containing mobile application- presented in Mobile application subsection.

9.3.1. Web service

Web service is an application deployed on the server that enables communication between a server and a client (web browser or another application). In order to provide communication with online database, such service is indispensable. To develop such an application Integrated Development Environment (IDE)[9] needs to be specify. For development of the web application (web service) Visual Studio has been chosen due to the reasons listed below:

~ Visual Studio contains a template for MVC (Model- View- Controller) applications that enables separation of each of layer and ease mapping of the database records into classes and further processing them

~ It fully support the chosen database

[7] Test Driven Development (TDD)- methodology of applications development that consists of continuous testing each functionality of the system

[8] Local- present on the device

[9] Integrated Development Environment- expert application dedicated for development of applications

~ Visual Studio is integrated with the Azure tool that provide 500MB of free hosting space for the web application. For make application usable, web service needs to be reachable from the internet

Technical details of the development approach are presented in the Table 16.

ASP.net version	**5**
Programming language	C#
Applied interfaces	IPatientEntity

Table 16: Technical details of development

Due to the fact that web application only needs to provide data for mobile application without presenting them, only Model-Controller part of MVC approach was used.

Model part of the system represents database records in the form of C# classes. Model classes that are used in this application are presented in below Figure 59 and Figure 60.

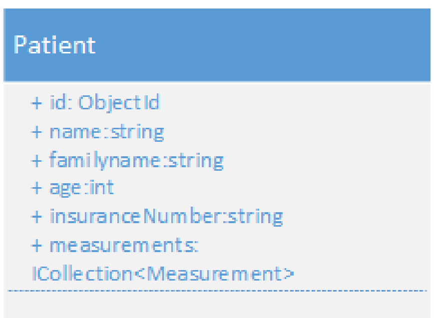


Figure 59: Model of Patient record

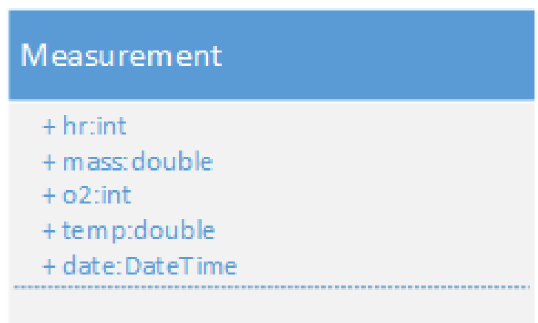


Figure 60: Model of Measurement record

All variables have types that enable sufficient accuracy and appropriate format of storing data. Respective formats of data are presented in Table 17.

Int	**Integer values**
Double	Precise values with decimal part
String	Word/phrases
DataTime	Date and time

Table 17: Types and respective data format

Having obtained models of data being processed, class that represents database operation need to be implemented. Its functionalities are ensured by the interface IPatientEntity that is presented in the Figure 61.

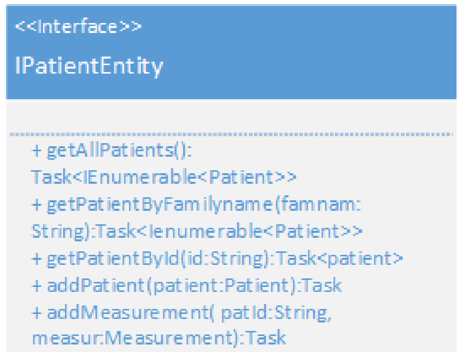


Figure 61: Interface implemented by database model

Generic object Task, indicates that implemented functions will be performed asynchronously and return proper object or collection. The synchronicity was applied to increase efficiency of the application during retrieving data.

Besides above models, appropriate control over that data should be provided. This point is realized by Controller part of MVC approach in class DatabaseController. While controller manages Internet connection, it uses methods of PatientEntityImpl that implements IPatientEntity interface for sending and receiving data.

DatabaseController is accessed from the level of the Internet via following routing path: "{server_address}/api/database".Direct access via GET method to that routing path results in complete list of all patient present in the database. All routing paths and respective actions are presented in the Table 18.

GET /api/database	**Complete list of patient**
GET /api/database/{id}	Patient with specified identificator
POST /api/database	Add patient to the database
POST /api/database/{id}	Add measurement for a particular patient

Table 18: List of managed web requests

Responses as well as requests are transmitted in the JSON format of data that is handled by database server[10]. JSON format is a format of storing key-values pairs in the pattern presented in the Figure 62.

```
{
    "key" : "value"
    "key2" : "value2"
    "array_key" :
        ["akey1" : "avalue1","akey2" : "avalue2"]
}
```

Figure 62: JSON format

[10] See details in chapter 11. Database

9.3.2. Mobile application

While web service enabling interface with database is already accessible from the point of the Internet, mobile application using HTTP protocol can be developed. As it has to be dedicated for tablets with Android operating system, Android Studio has been chosen as an appropriate IDE. Java has been chosen as a programming language for a mobile application. The reason for that choice was that fact that Android Studio is the only one tool officially supported by the Google Inc. which owns rights to the Android Operating System (OS). General technical information about the tablet components versions is presented in the Table 19.

Name:	**Version:**
Application version code	1.3
Minimum Android API[11] version	15
Target Android API version	23
Java	1.8

Table 19: Versions

Android application is supposed to be a tool dedicated exclusively for nurses that enables to handle with the complete hardware system for performing measurements. It provides a nurse following operation, indicated in a use case diagrams in Figure 63 and Figure 64.

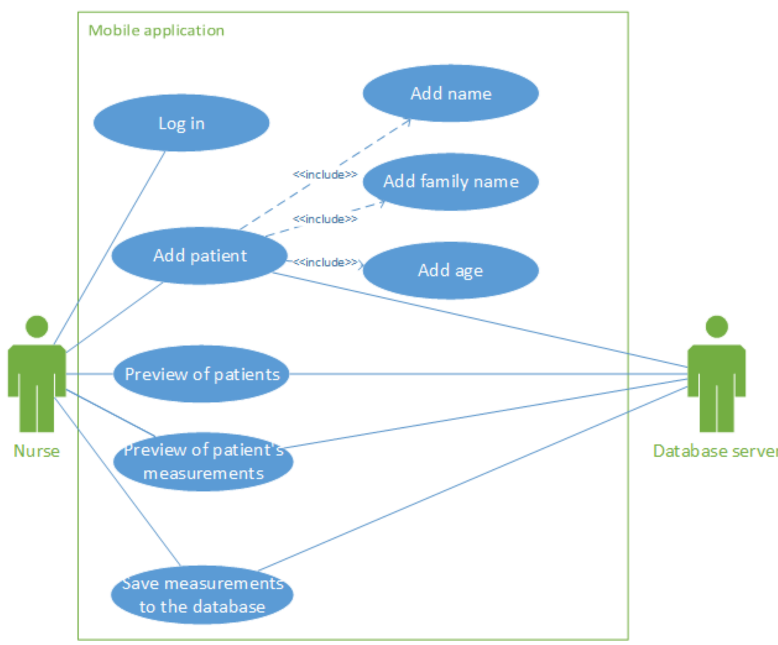


Figure 63: Use case diagram for integral operations of the mobile application

[11] API, Application Programming Interface- is a tool that provides specific methods and data structures for a particular application

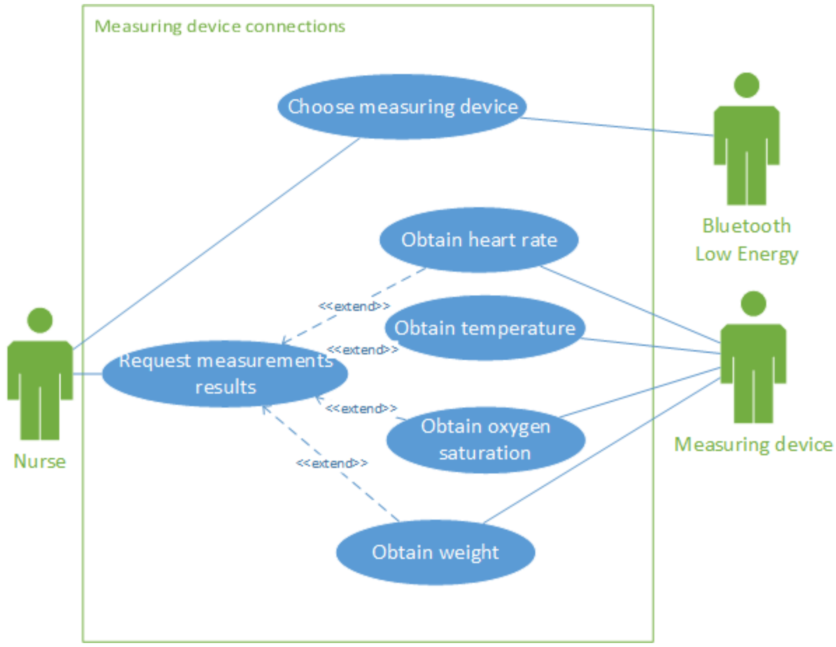


Figure 64: Use case diagram of requesting measurements from the device

All actions pointed above are assured by cooperation of the classes which is presented in a general class diagram in Figure 65. Every class is defined in details in the diagrams from Figure 66 to Figure 73.

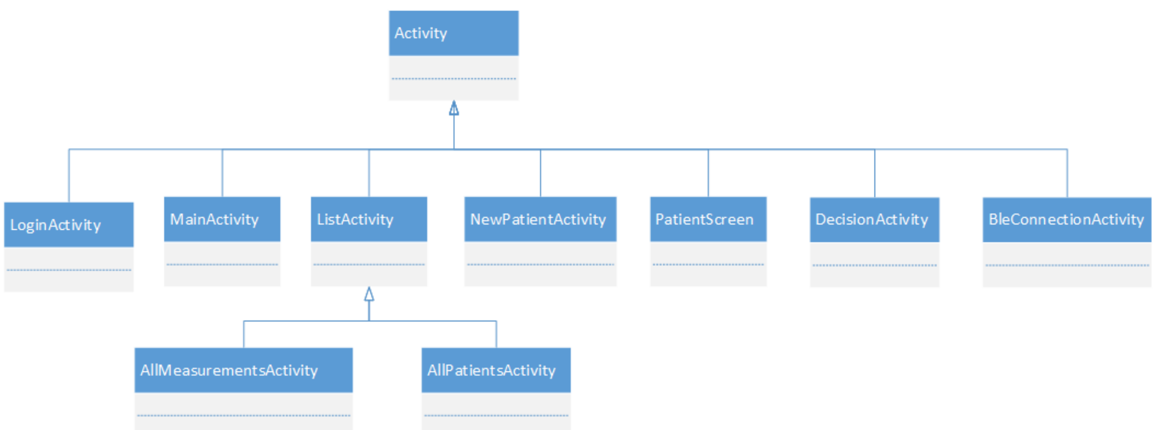


Figure 65: General class diagram of the Android application

Classes Activity[12] and ListActivity are provided as a part of Android API thus the report does not include their description.

---

[12] Activity- is a class that provide a separate view for the application

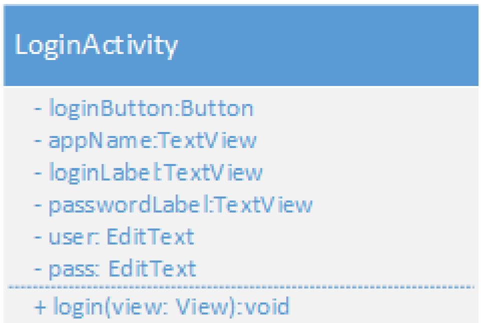


Figure 66: LoginActivity class diagram

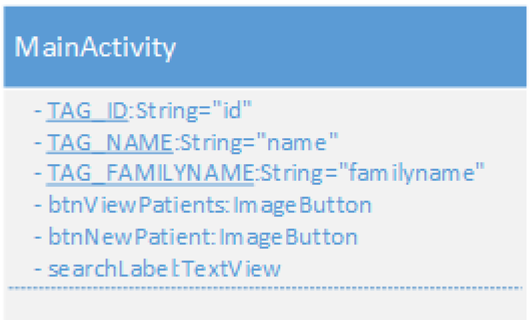


Figure 67: MainActivity class diagram

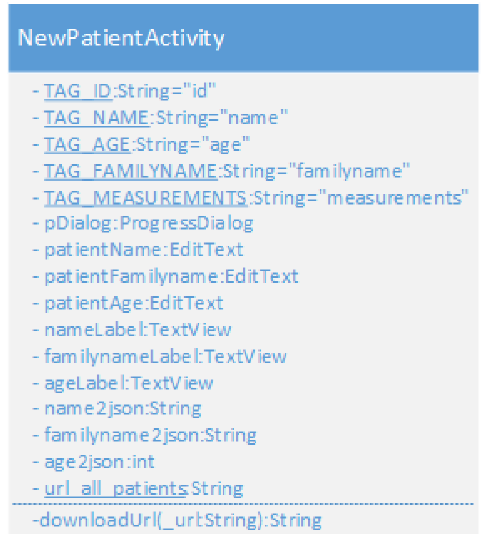


Figure 68: NewPatientActivity class diagram

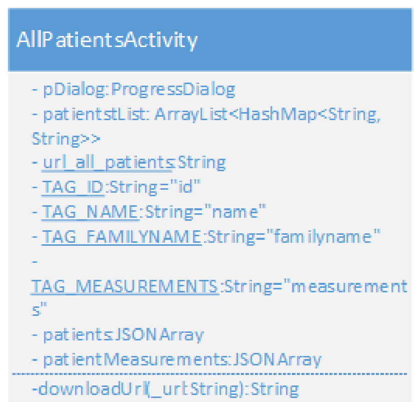


Figure 69: AllPatientsActivity class diagram

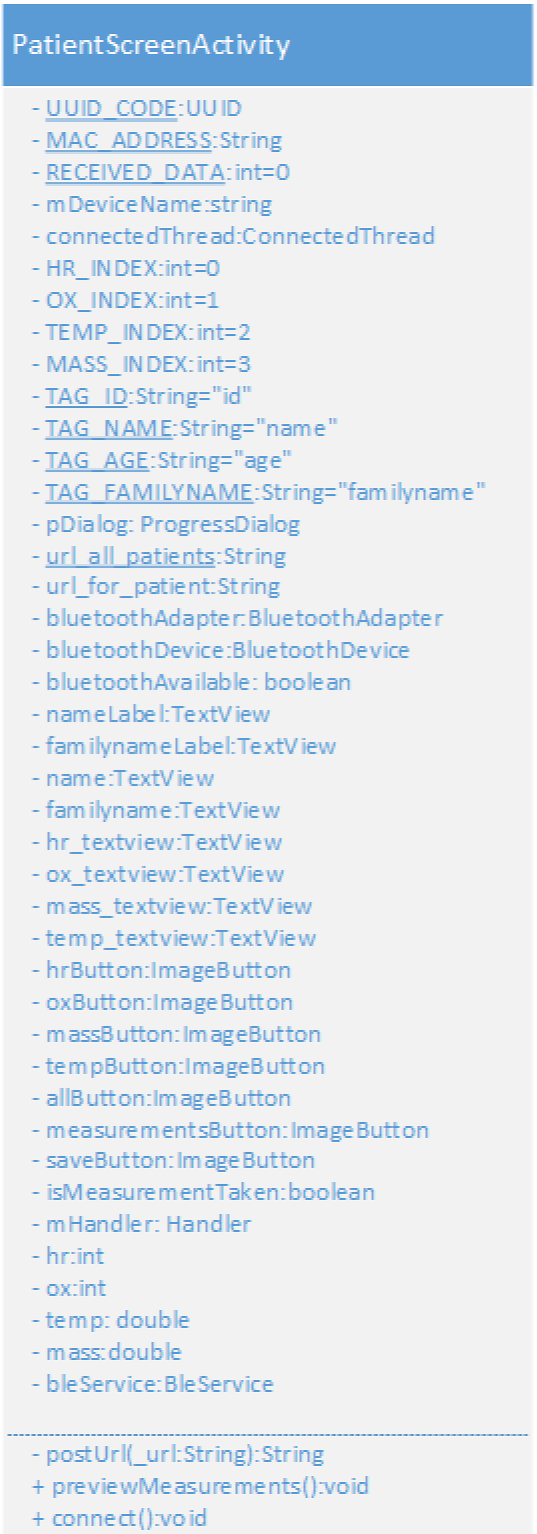


Figure 70 PatientScreenActivity class diagram

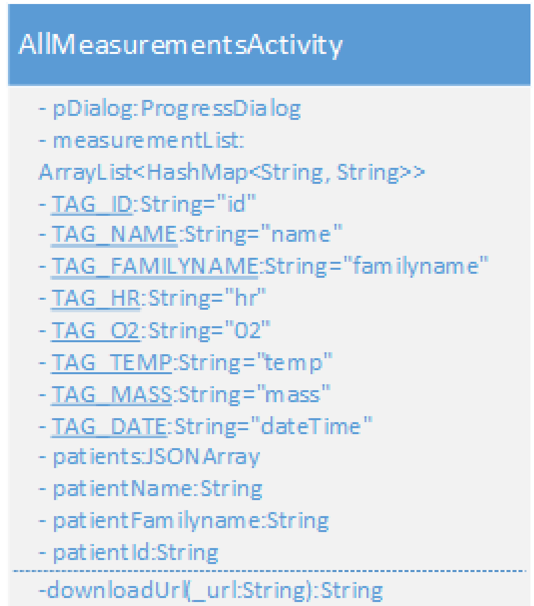


Figure 71 AllMeasurementsActivity

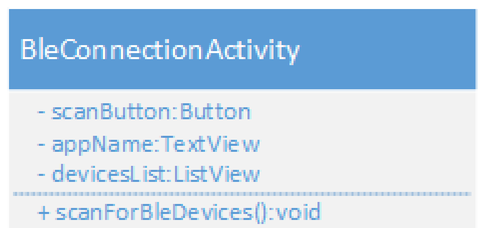


Figure 72: BleConnectionActivity class diagram

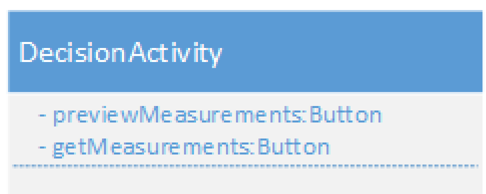


Figure 73: DecisionActivity class diagram

Mobile application consists of the seven distinguished views that are contributed by the particular classes inheriting from Activity base class.

The transitions between activities are presented in the state-transition UML diagram in Figure 74.

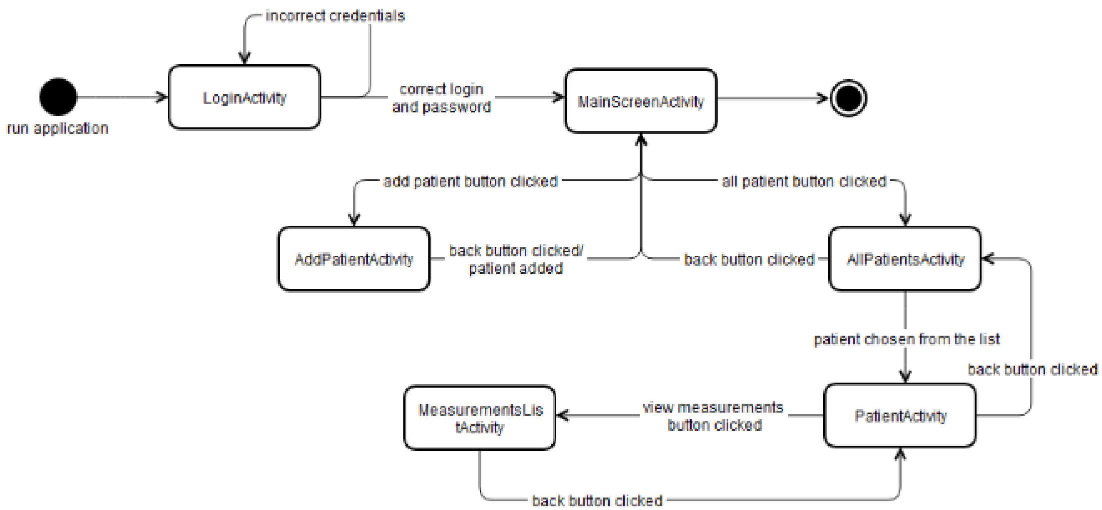


Figure 74: State transition diagram of mobile application

For appropriate working of the application Internet connection and Bluetooth have to be enabled, otherwise proceeding will not be possible. In case of lack of any of required connection, Toast information will be shown in the bottom of the screen when trying to continue. To prevent irreversible operations on the database, remove and update functions are disabled in the application and can be performed only by the administrator of the database from the level of mongoDB dashboard.

Login Activity

The outlook of LoginActivity is presented in the Figure 75. It is first view that user can notice after running the application. In the screen two text fields are present and icon button.

Figure 75: LoginActivity

First text field concerns login to the application, the second one contains password. The icon represents button that starts next activity if and only if login and password were input correctly. The appropriate input formats of the text fields are presented in Table 20.

Field:	Text type:
Login text	Text
Password text	numerical password

Table 20: Appropriate format of input of text fields in LoginActivity

Main Activity

This activity enables a nurse choosing desired operation neither adding a new patient nor reviewing all

Figure 76: MainScreen activity

database records. The content of the activity is presented in Figure 76.

Both icon are presented together with labels. First button let a nurse look for a particular patient using his/her family name or review list of all patients when the text field above is left empty. The second button allows a nurse to add new patient to database. Both operations require Internet connection.

AddPatientActivity

The activity AddPatientActivity was designed so that a nurse can introduce new patient into database filling necessary text fields. Mock-up of the view is presented in the Figure 77.

Appropriate formats of all text fields are presented in the Table 21.

Figure 77: AddPatientActivity

Labels:	Type:
name	Text
family_name	Text
age	numerical value
Insurance number	Key

Table 21: Formats of text fields in AddPatientActivity

All pieces of information about a patient needed to be filled to add patient properly. A nurse will be notified about correct addition of a patient by Toast information in the bottom of the screen.

AllPatientActivity

AllPatientActivity enables a nurse reviewing of all patient present in the database. Patients are presented in a form of a list where each record is separated by a line. Preview of all patient contains only a name and a family name of a patient, although, there is additional field, hidden for a nurse, that contains id of each patient- this field is auxiliary information that allows the application to transmit an unambiguous identifier of the chosen patient. Preview of the activity is presented in the Figure 78.

Figure 78: AllPatientActivity

The data obtained by the device are displayed in standard units according to Table 22.

Vital sign:	**Unit:**
Heart rate	bpm (beats per minute)
Temperature	˚C (Celsius degrees)
Oxygen saturation	%
Weight	Kg

Table 22: Units of respective vital signs

DecisionActivity

Decision activity is a screen that allowed better flexibility of functionalities of the mobile application. Separate functionalities of data preview or obtaining data has been provided. This approach let nurses using application either to browse patient measurements whereas measuring device is not available or gathering measurements otherwise. Mock-up of this activity is presented in the Figure 79.

Figure 79: DecisionActivity

BleConnectionActivity

The BleConnectionActivity fulfils a criterion of a system independent on measuring device. Having conducted tests of an initially proposed wrist band- Angel Sensor it is supposed not to be suitable for the system being described in this paper (For details see chapter Smart wristband). Based on that fact, it has been decided to make application able to cooperate with different measuring devices as long as they satisfy Bluetooth Low Energy standards.

The view of this activity is presented in the Figure 80.

Figure 80: BleConnectionActivity

Having enabled Bluetooth service on the device, the application is able to detect Bluetooth Low Energy peripherals. Scanning can be enabled by choosing blue button with the logo of Bluetooth. Scanning timeout was fixed to five seconds, after that time button needs to be chosen again to continue scanning. All detected peripherals will be presented in the form of list in the upper part of the screen. In order to proceed, a user has to choose device which will be connected to the application.

PatientActivity

This view is the one that enables a nurse to request for measurement by clicking appropriate icon. The obtained value will be shown in the respective circles on the left of the button. Four grouped upper buttons use Bluetooth Low Energy protocol in order to request the measurement hardware for the results. The bottom three buttons are responsible, respectively, for saving obtained information in the database by sending POST request via HTTP protocol (Button 1.), requesting for all measurements simultaneously (Button 2.) and saving obtained measurements to the database (Button 3.). In case that not all measurements were called (for example: only one was necessary) the rest of vital signs will be replaced by default value respectively: 0 for the heart rate and the oxygen saturation and 0.0 for the weight, the temperature. Data of the measurement is always set automatically. The bottom left icon makes possible displaying complete list of all measurements concerned the given patient. Below, in the Figure 81. Outlook of the PatientActivity is presented.

Figure 81: PatientActivity

Figure 82: Button for retrieving data

Figure 83: Button for requesting all measurements

Figure 84: Button for saving data

The application uses Bluetooth Low Energy standard (see Appendix A) for communication with a wristband. Therefore PatientActivity requires Bluetooth module turned on to start. In case of disabled Bluetooth, application will ask user for confirmation of turning Bluetooth on.

To prevent requesting Bluetooth data without established connection, after opening activity, BroadcastReceiver has been implemented so that changes in Bluetooth adapter states can be detected and application can undertake a proper action.

To prevent undesirable Bluetooth access, the application is able to establish connection only with a device whose MAC[13] (Media Access Control) address complies with that one included in the software.

MeasurementsListActivity

This is the activity that displays all measurements for a chosen patient, stored in the database. The data is displayed in following order: heart rate (marked as HR), oxygen saturation (SpO2), temperature (Temp.), weight (Mass), and date (Date) in the format yyyy-dd-mm, as it is shown in the Figure 85.

Application does not enable a nurse removing neither a measurement nor a patient from the database.

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[13] MAC address- is a hexadecimal, 24-bit address that enables unambiguous identification of a device in a net

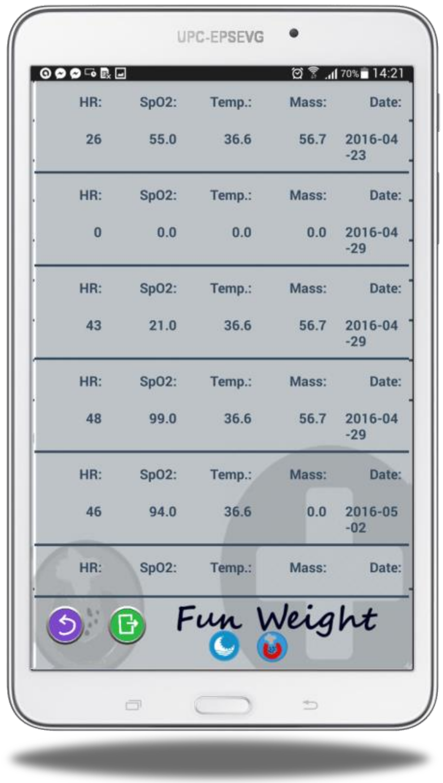


Figure 85: MeasurementsListActivity

9.4. TESTS

In order to check utility of the user interface, designed taking into consideration various guidelines and studies indicated in the Design section, usability tests have been conducted. Final design is presented in the Development subchapter. Stage of test has been divided into three sections:

- experts evaluation
- online survey
- real scenario evaluation

Thanks to experts' evaluation useful information has been obtained to increase usability of the interface. On the basis of their feedback, several improvements have been introduced in the application, namely:

- grouping buttons of similar functions
- enlargement of value font size

Having adapted experts' suggestions, online survey, has been created on the basis of suggestions included in [46]and [47].It aims at wide audience in the issue of icon meanings and interface understanding. The survey consists of nineteen sections (steps). Step first poses information about reason and goal of the survey. Steps from two to fourteen concern understanding of the given icons used in the application, see Figure 86.

Figure 86: Set of icons used in the application

Each icon has been proceeded with the question: "What do you think the above icon mean?"

Obtained results are presented in the Table 23.

Icon	Correct understood [%]	Incorrectly understood [%]
	**100**	**0**
	**20**	**80**
	**90**	**10**
	**78**	**22**
	**40**	**60**
	**90**	**10**

	**50**	**50**
	**40**	**60**
	**78**	**22**
	**20**	**80**
	**90**	**10**
	**90**	**10**
	**90**	**10**

Table 23: Understanding icons results

Afterwards three sections concerning interaction has been created.

First section consists of image like this shown in the Figure 87. And scale to choose whether presented interface is easy to understand where one means **STRONGLY DISAGREE** (interface is not easy to understand) and five **STRONGLY AGREE** (it is easy to understand). Results are presented in the Table 24.

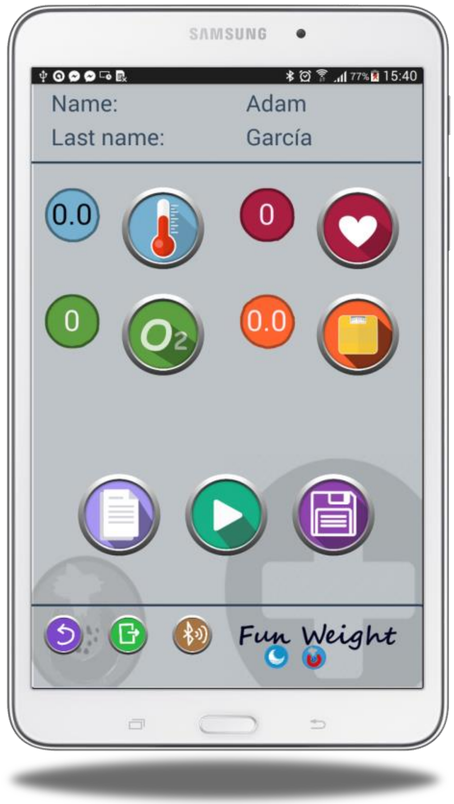


Figure 87: Image presented to the user during interaction valuation

Grade	Percentage [%]
1 (difficult to understand)	11.1
2	0.0
3	33.3
4	33.3
5 (easy to understand)	22.2

Table 24: Results of online survey

According to survey's result 78% of interviewees correctly identified function of small round icons with numbers.

The second section evaluates appropriate understanding of navigation design in the application. The button for addition a new patient had to be chosen by a participant according to image presented in Figure 88. Moreover element that lets search for desired patient family name has been asked to the participant.

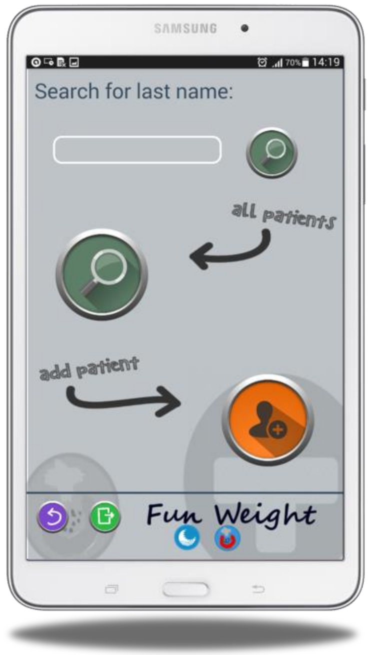


Figure 88: Image presented to the user during interaction valuation

As in case of first section about interface, also for this participants had to evaluate how easy it is to understand. Scale is the same as in case of Table 25.

Grade	Percentage [%]
1 (difficult to understand)	11.1
2	22.2
3	22.2
4	33.3
5 (easy to understand)	11.1

Table 25: Results of online survey

According to performed research 80% of participants correctly indicated Add new patient button and 40% of them appropriately have chosen element for searching a patient with a given last name.

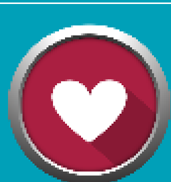
The third section was involved with view presented in the Figure T. A participant had to name a function of small rounded icons with numbers and to rate in the scale from one to five readability of that screen, where one means that interface is not readable at all and five means very readable interface.

Overall rate of readability of the views presented to the participants has reached a level of 3.33 what might be interpreted as a moderate ease of interface interpretation. However the most crucial information extracted from the survey concerns possible source of confusion that need to be limited as well as suggestions of interviewees. Having improved interface elements, survey should be conducted again in order to evaluate actual increase of comprehensibility of the use interface.

The last but one section of the survey included recommendations and descriptive feedback for the designer. Below questions have been asked there:

- ~ How would you describe interface in a few words?
- ~ If you could change anything in that interface, what would it be?
- ~ What do you like the most about that interface?
- ~ If you have any suggestions, share them with us.

On the basis of survey's result some sources of confusion might have been realized, especially in terms of icons' ambiguity. So as to avoid misunderstandings, improvements indicated in Table 27 have been introduced.

Confusing design	Confusion description	Improved design
	Previous outlook of this icon has been often associated with love or "add to favourite" activity instead of **heartbeat**.	
	The previous icon has been understood by some participants as "lock" button instead of **log in**.	
	The former appearance of the button was, in most cases, treated as a button for generation a new document instead of **browse measurements history**.	
	The function **connect with measuring device** has not been identified correctly by the previous outlook of the button.	
	While the button with magnifier has been unambiguous for **searching for a given patient**, it was confusing as an icon for **browsing** all patients/ As a	

	result two separate buttons have been created	 

Table 26: Old and improved GUI elements

The other part of the tests was contributed by real- scenario tests that had to evaluate usability and ease of the interface during particular tasks involved with functionalities of the application. This kind of test have been performed on the application improved comply with survey results.

Actual usability tests performed on the real device have been constituted by eight following tasks to do by participants.

1. Log in to the application
2. Add a new patient
3. Browse all patients
4. Return to previous view
5. Find the patient with a given last name
6. Browse measurements history of a given patient
7. Connect with a Bluetooth device
8. Log out from the application

For each task, interviewees had to estimate ease of the task choosing appropriate grade on the scale where: 1 meant trivial to do and 5 signified undoable. Average rate of ease for each task is presented in Table 28. During trials, user's activity has been recorder so as to apply natural user behaviour for adjusting the interface.

Task number	Average rate of ease
1.	1.57
2.	2.71
3.	1.14
4.	1.00
5.	2.29
6.	1.88
7.	4.43

8.	1.00

Table 27: Average rate of ease for real usability tests

Having obtained above results as well as feedback from participants, several conclusions might be drawn. A qualitative evaluation of the user interface has revealed that it is relatively easy to follow some kind of commands intuitively. However, some tasks, mainly connection with Bluetooth measuring device posed a challenge for some interviewees. Based on user behaviour during test, guidelines for further interface improvement might have been extracted. To main suggestions concerning enhancement, at least following ones should be included:

~ Signing in activity should be also performed by clicking DONE button on a virtual keyboard. Currently it is confusing for users and it takes a while for them to realize that additional button needs to be clicked.

~ Button for requesting measurements should be more obvious in terms of Bluetooth connection. During performing of this task, most of interviewees asked for help, because connecting with Bluetooth device was not understood as a step required for obtaining measurements.

~ Searching for a patient should be realized by matching similarity rate[14] rather than matching a complete patient's last name. Current solution might be annoying for users, because having typo in the search field no patient will be found. Matching by similarity makes searching more intuitive and robust.

~ Sometimes, time necessary for changing for changing virtual keyboard[15] from a text one to a numeric one introduces a bit of confusion. Nevertheless, time of switching keyboard is not dependent on the application implementation

[14] Similarity rate says how one thing is similar to the other. Here similarity of two words, made according to comparison of succeeding characters

[15] Virtual keyboard- is a keyboard that is displayed in the screen of mobile devices

9.5. DATABASE

Among all available databases only two types can be distinguished: SQL[16] databases or noSQL databases. SQL databases, called also relational databases have form of tables that are connected some relations. All tables contains primary key that enables unambiguous identification of each record. Relations, in turn, are realized by possession of the primary key of a table. In such a way, given record in the one table references to the other in another table. NoSQL database have form of a set of the documents that described completely each record.

In the project, the second option has been chosen- mongoDB database provided by website mLab.com. The reasons for that are listed below:

- mLab provides online database server with capacity of 500MB for free (can be upgraded)
- It is fully compatible with Azure web services
- It supports mongoDB Driver for C# language
- It provides better scalability [48]
- It does not require rigid in advance scheme [48]
- It assures less data redundancy due to the fact that keys are not repeated in tables

However it has also one drawback. MongoDB Driver process documents of the size at most 16MB according to [49].

9.5.1. Security

Security constitutes a critical factor of all information system, but it is particularly crucial in case of medical systems that stores so called sensitive information. As it is stated in [50] , sensory data, that are subject of our project, are not a part of sensitive data. Nevertheless, there should be provided sufficient security policy in case of integration database with Electronic Health Records of the hospital.

Comply with information obtained from Director of Innovation Department of the hospital, currently, data are stored locally- on the servers inside the hospital. This solution is said to be outdated in other market branches. Again, according to the paper [50] where author proposes a novice topology of a hospital network that introduces solely one difference- outsourcing of the database from the third- party company, saving money[17] was indicated as a major benefit of such solution. Moreover it could also be the first step for improvement of data exchange between hospitals where given patient is being treated. Currently, forwarding of patient data is realized in a paper form which is meant to be not efficient and expensive way of communication, especially in a case of sensitive information.

Only one doubt about out-sourcing database indicated by the hospital was fear of huge dependence on Internet connection provider and rather lack of connection or not sufficient power of the connection, however, nowadays this fear may be perceived as not relevant, taking into consideration rapid development of Internet infrastructure.

[16] SQL- Structured Query Language used for manipulation of data in relational databases
[17] Reduction of costs is involved with paying only for real usage of the database

The current prototype does not adapt any of the below solutions. They will be taken into consideration in the further stage of the development.

The application, designed as a part of the project, contains a several of security vulnerabilities involved with activities listed below.

- Unauthorized access to the application
- Unauthorized access to the database
- Sniffing[18] of the Bluetooth connection
- Sniffing of the Internet connection

The influence of these vulnerabilities has to be diminished as much as possible before the deployment into production. The activities that have been undertaken to prevent above susceptibilities are respectively presented below.

Unauthorized access to the application

Unauthorized access to the application can result in performance of unsupervised measurements and obtaining measurements of all patients in the database. Although database applied in this application will not contain the sensitive data because it is separate and will not be integrated with the current hospital's one, unauthorized access should be impossible. In order to fulfil this condition, access to the application is enabled only after appropriate signing in with the username and numerical password provided by an administrator. Process of signing in is realized by LoginActivity that is the first view after running the application. Open session is valid until a nurse will log off. This will be prompted by the window of shown after pushing back button in MainActivity.

Unauthorized access to the database

The database used in the project is provided by the mLab server. It is online database which causes the problem of undesirable access to the data via Web service (designed as a part of the project also). In order to prevent unauthorized access two solutions can be applied, one involving preventing and the other one-encryption. The first one consists of enabling access to the Web service only for the particular MAC or IP addresses [9]. But the other engages using cryptology to encrypt transmitted data [51].

Sniffing of the Bluetooth connection

Sniffing of the Bluetooth connection can result in two distinguished ways: either stealing patient measurements or a false substitute of the data- integrity thread. According to National Security Agency, Bluetooth technology can be perceived as a relatively secure by using the pre-shared key authentication. During pairing devices a key is established that is later used for both authentication and encryption of the data [52]. A connection manager was implemented as a consensus between the comfort of use and security precautions pointed out in the paper [52].

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[18] Sniffing- a term used to name eavesdropping in the network

Sniffing of the Internet connection

As well as point third, sniffing of the Internet connection enables malicious operations on the transmitted data and database. One of the possible solution of this problem is to disable global access both to the application and database by using only the local network for all processes. It results in significant decrease of the thread, however in order to make it secure also in the local network, encryption techniques should be applied as in the case of the Bluetooth connection.

10. Interactive Game

10.1. INTRODUCTION

Firstly the definition of an interactive game, it consists of an adjectives and a noun. The first is the adjective namely interactive:" (of a computer program or system) interacting with a human user, often in a conversational way, to obtain data or commands and to give immediate results or updated information" [53].

And the second part is the noun namely game:" an amusement or pastime" [54].

This forms our understanding of the interactive game on itself as: An object which obtains data (in example the press of a button) and replies with a certain action (in example lighting up an area) for the purpose of amusement of the user. Further on the game which was created for this project will be thoroughly explained.

Decreasing stress and anxiety of children during the measurement of the vital signs is the objective of this project. This can be achieved by distracting the child on amusement, which is applied in our solution.

While there are countless games on the market today, the decision to create a new game had several reasons. One of them being the intention of relating the game to the Hospital and mainly to the medical envoirment. The game integrates the measurement of height and weight of the child in itself. Another reason was to allow adjustment of the game on the child's needs and age, since the age of the group of children on which we focused was between three and ten years. The interest and understanding of the game can be different in this category of children and so the resolution would be to adjust the game for different factors. The fear of child's excitement existed since amusing a child often leads to excitement of the child which will influence the measurements accuracy. Which will be countered by the simplicity of the game.

10.2. USER CASES

The importance of the right interpretation of the user aspiration and the requirements are an essential part to deliver a suitable outcome.

There are two user groups, the children who will play the game and the nurses who are utilizing the game for the distraction of the children. Both groups have certain requirements and expectations from the game, firstly we will look at the children's needs and expectations.

10.2.1. Children

Children being unaware of the main goal see amusement as the main goal of the game. This needs to be achieved without exciting them and without unnecessary interruption of the envoirment. We propose the placement of the game in the waiting room (now Arcolris room) to avoid the placement of the children in an unknown and more intimidating room for them. The game can be shared with more than one patient and there is an option implemented to turn of the sound if a more silent envoirment is desired.

The main user story of the child that is using the game is: As a player I want to amuse myself so that I relieve my stress.

The use case of both modes of the game is presented bellow in figure 89.

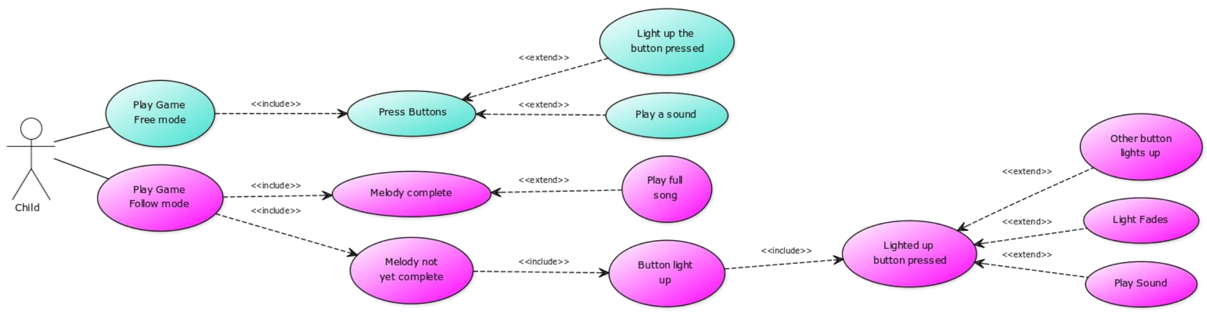


Figure 89: Use case for children

While the first mode is active which we purpose for younger children consists of playing with the game by pushing on buttons. By pressing the button, it will light up and if sound is on it will produce a sound which is unique for the button. This will continue until the game is quit.

While the second mode is active which we purpose for older children exist of a pre-programmed melody that will be indicated by lighting up the correct button according to the sound which should be played. When the button is lighted pressing another button won't produce light or sound. When the correct button is pushed the light will turn off and if sound is on it will be played, followed by lighting up the next button (which should be the next note in the melody). When the full melody is pushed right in the game the song will play one more time completely from the start. This mode can be prematurely quit or will end after the full melody is played.

10.2.2. Nurses

The nurse also has other expectations from the full system like measuring the vital signs. This requirements are discussed in the chapters which discuss the parts that are suited to satisfy that particular requirement. The requirement used in the example above are discussed in the chapter of the application (measuring the vital signs).

The next scenario is centred about the nurse.

- As an observer I want to initiate the game so that I can determine the desired mode.
- As an observer I want to control the duration of the game.
- As an observer I want to be able to turn the sound on and off before the game starts so that I can minimalize the interruption of the envoirment.

The nurse can select the mode by pressing the first or the second button before the game starts. Which will determine the mode, after the game is selected and quit (by the nurse) the nurse can reselect the mode.

The duration of the game can be controlled by reselecting the game for a second game (applicable to the second mode) or by ending the game manually. Manually the game can be ended by pressing the tenth button for three times in a row.

The sound can be turned on or off by the third button before game starts, when sound is active the third led will be burning before the start of the game. If the sound is deactivated the third led will be off before the game starts (multiple changes in a row won't affect the functioning and will be on or off depending from last entered comand by the nurse). During the game it is impossible to turn the sound on or off.

The use case which is explained above is visually presented bellow in Figure 90.

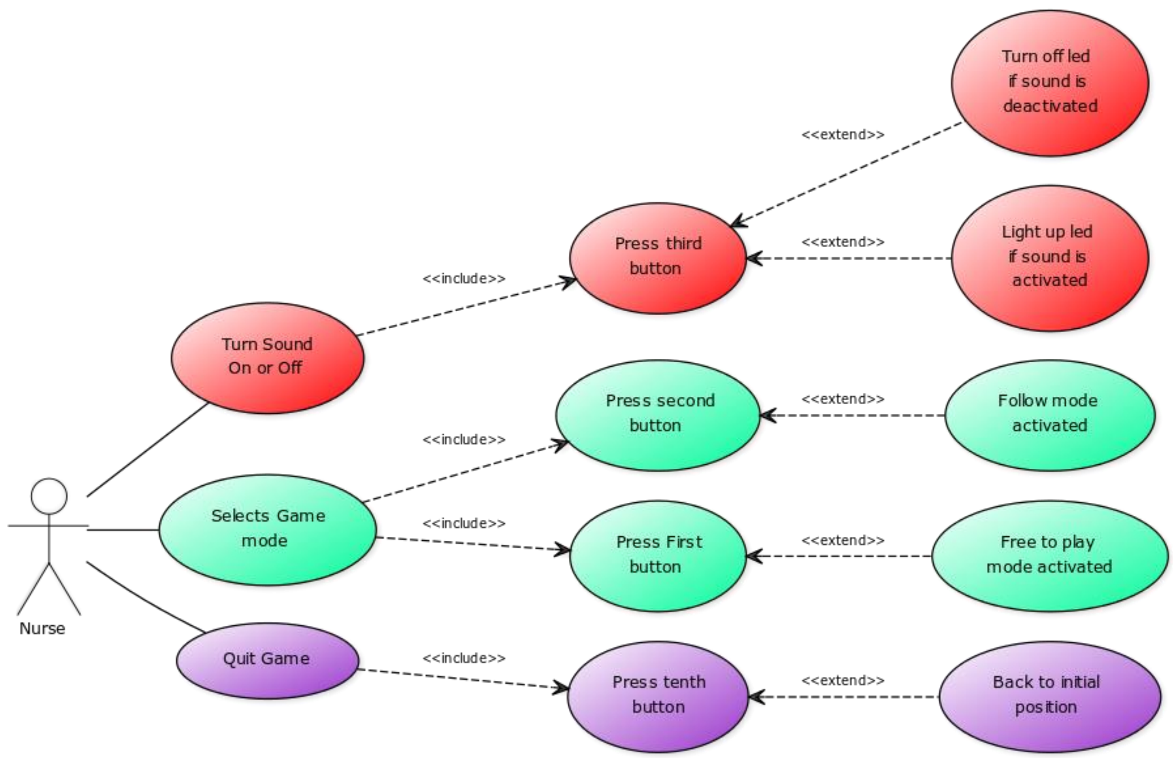


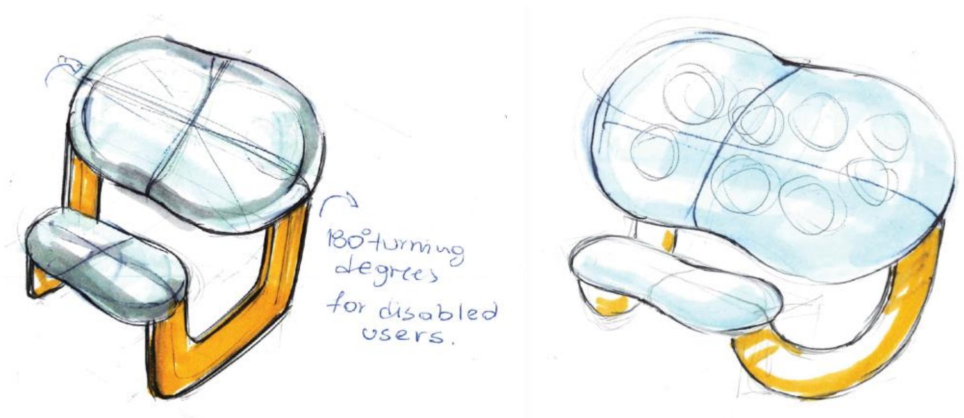
Figure 90: Use case for nurses

In the next chapter the design of the game and the main idea with their reasoning will be centralized and explained.

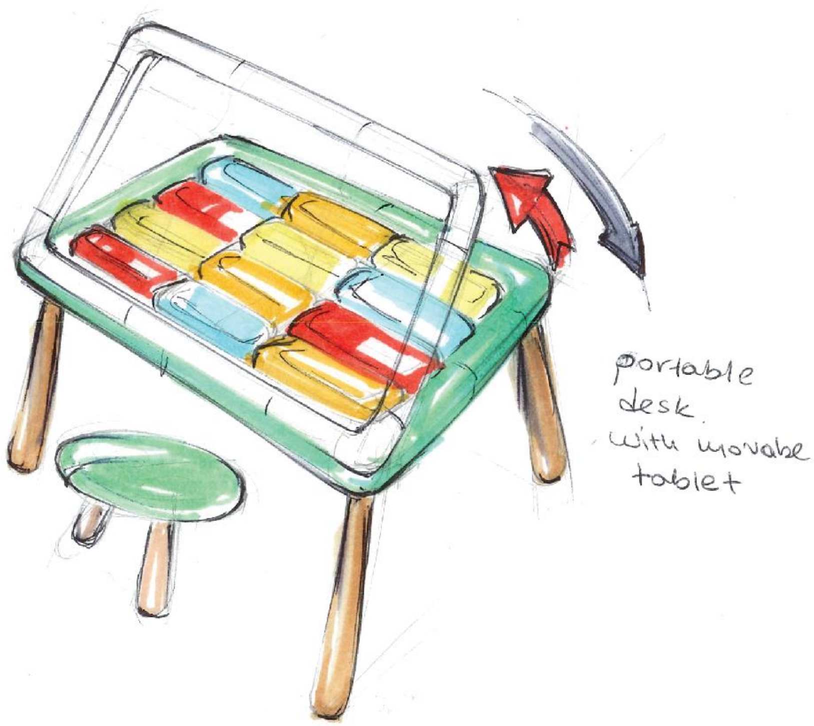
10.3. DESIGN

Music, it has often been used as a mean for calming children before their hospitalization or surgery. By taking this into consideration, we decided to develop a game that would actually co-work with the smart wristband that it will be used and also interact with the children so as to distract their thoughts from the upcoming surgery. The main idea of the game, is to use Arduino technology and large buttons which would light up and kids could press them and play music. In cases of the younger kids, it would be a random selection which children could do and create their own tunes. In older ages, young patients will have to follow a specific "route" that would be indicated by lights and produce already existing melodies. The main advantage of this game compare to existing devices, is that it can adjusted in the level and age of the children.

The first concept idea is based in the traditional school desk, that it has been used for many years either as a learning game or in educational environments. This compact product, combines desk and chair in one piece, so it is easier for transferring it in different rooms. Moreover, it is usable for wheelchair users, since its main tablet can be turned 270 degrees and used from the other side of the chair.



An alternative option of this desk is a most common version of desk and stool where the kid can play music using the buttons as seen in the following picture. In this case the main tablet is portable so the child can adjust in the angle that is more comfortable and easy to use. This feature, makes the game more similar to adults-used computers, therefore children are more intrigued to use it since it looks like their parents devices. The use of bright colours are used for being more children-friendly and interesting in eye.



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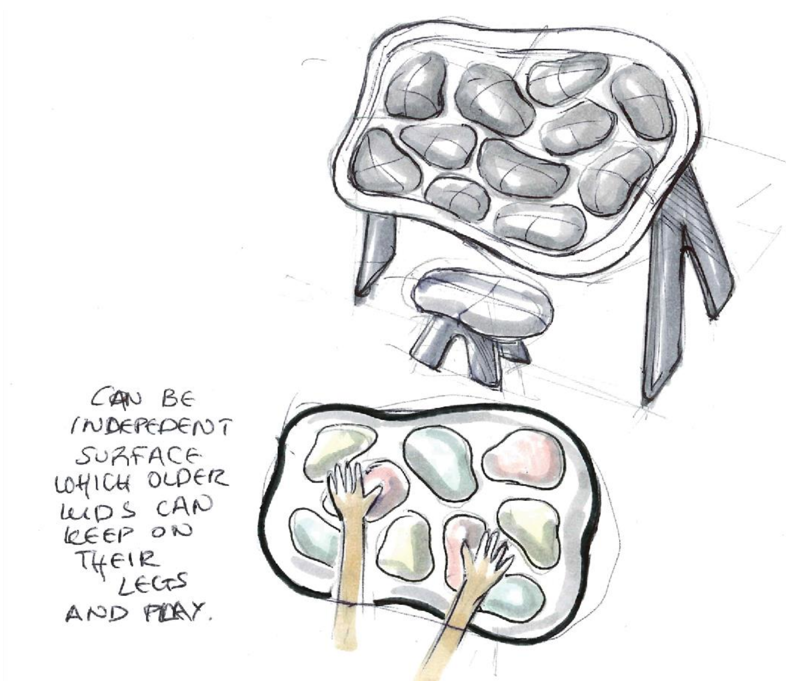
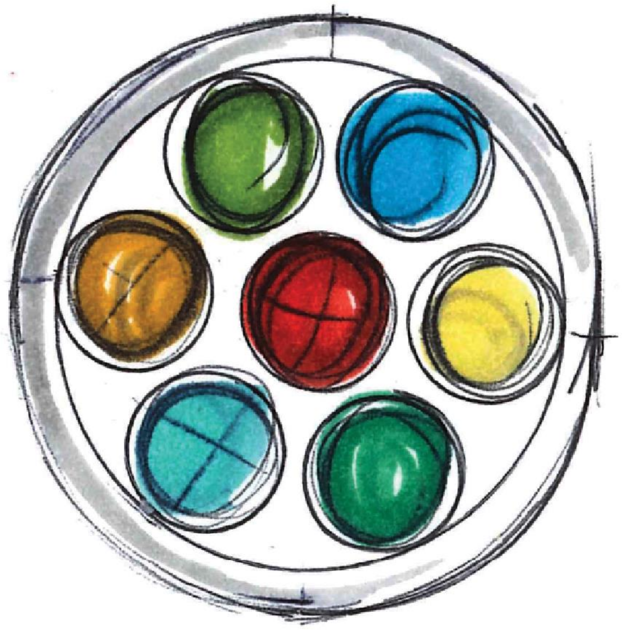
In this design, there are organic shapes integrated, more suitable for younger ages where they can explore the feeling of touch. The tablet is fully portable, that means that older children could just use them separately from the frame and keep them on their knees while playing music.

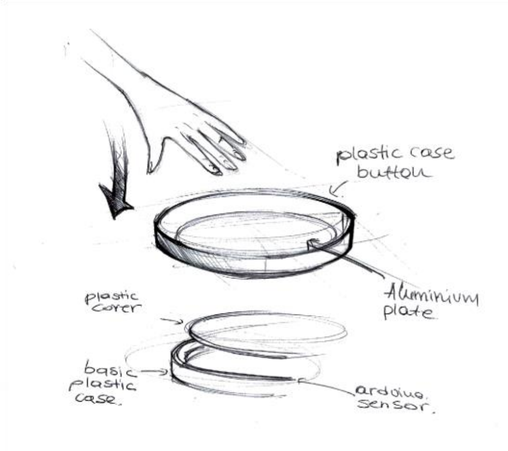




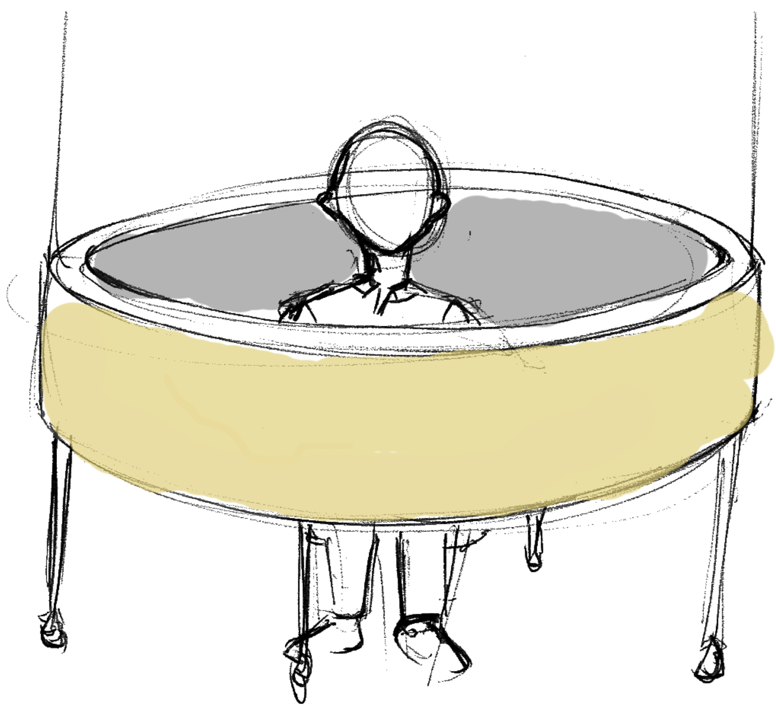
A more independent device which young patients could use in any part of the hospital as a distraction. The young patients could share it with other children or their parents while they are playing in different rooms.

In the following sketches the idea that it has been developed, is similar to the well-known drums kits. The user just using its own hands for pressing the buttons which light on, and play some music. The idea behind it is not only distract kids from the upcoming surgery, but also familiarize children with playing instruments in case that they have not before. Moreover, the game it can be expandable, since as more circle tables are added, it can be enlarged and more people could participate. It could be placed in the waiting room and children could socialize with other patients, or playing with their family.

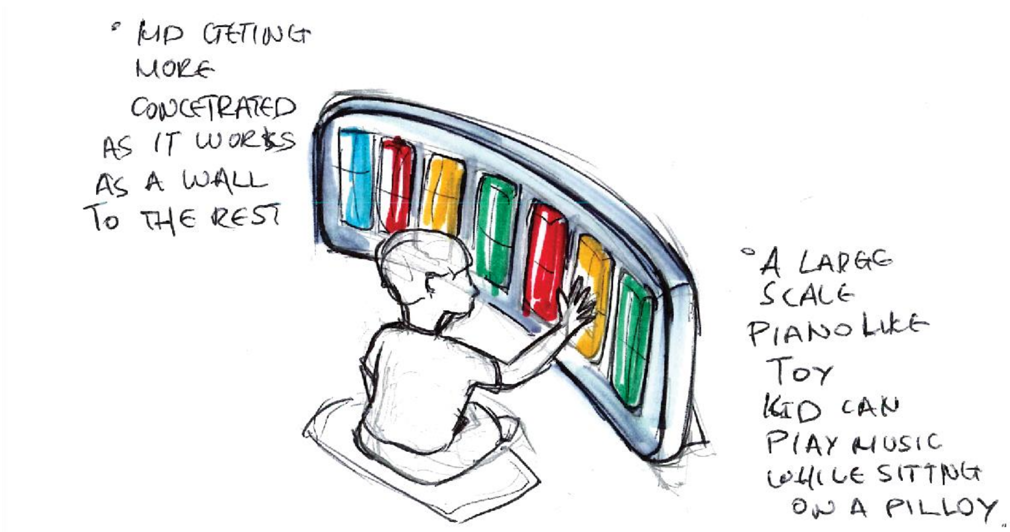
Music table.


plastic case
button
Aluminium
plate
plastic
cover
basic
plastic
case.
arduino
sensor.

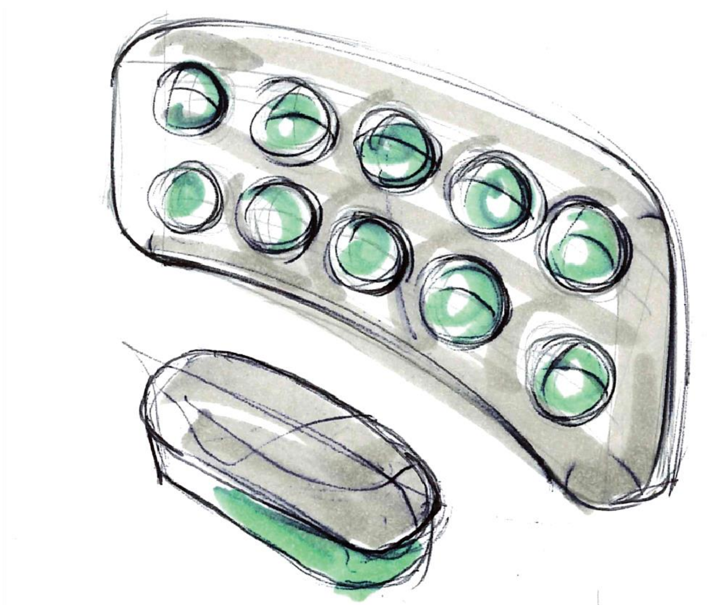

alternative 1
for legs.



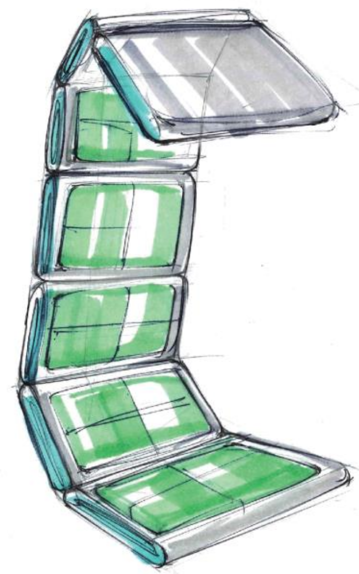
Another idea is to create a small circle which allows the patient to sit inside and have a 360 degrees all around it. The child would be focused on the game more instead of been distracted and getting stressed from the processes which are happening in the hospital. In that case the child's attention is not in the conversation between the parents and medical staff, but absorbed in his game.

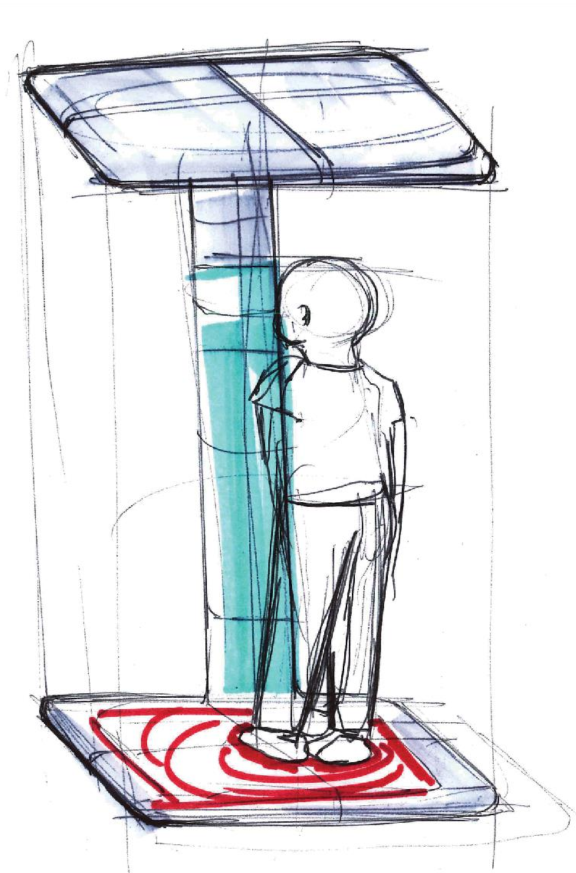


As a development of the previous idea, those games, are bended screens which allows children to be enclosed and focused on the game. At the same time the kid sitting on a pillow on the floor so as to feel like being on his own bedroom and playing and familiarize himself with the environment. An enclosed scale in the pillow, would measure the weight of the patient and then it will be sent in the application.

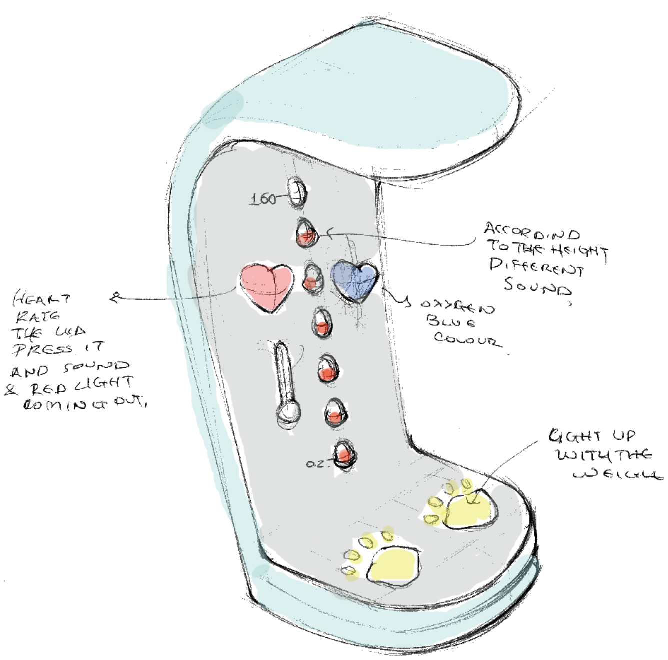


In continue, more features were implemented in the game so as to enhance the experience of the kid, and connect it to the measurements. With this kind of design the numbers of height and weight are taken automatically when the kid start playing the game. Lighting and sounds will be available.



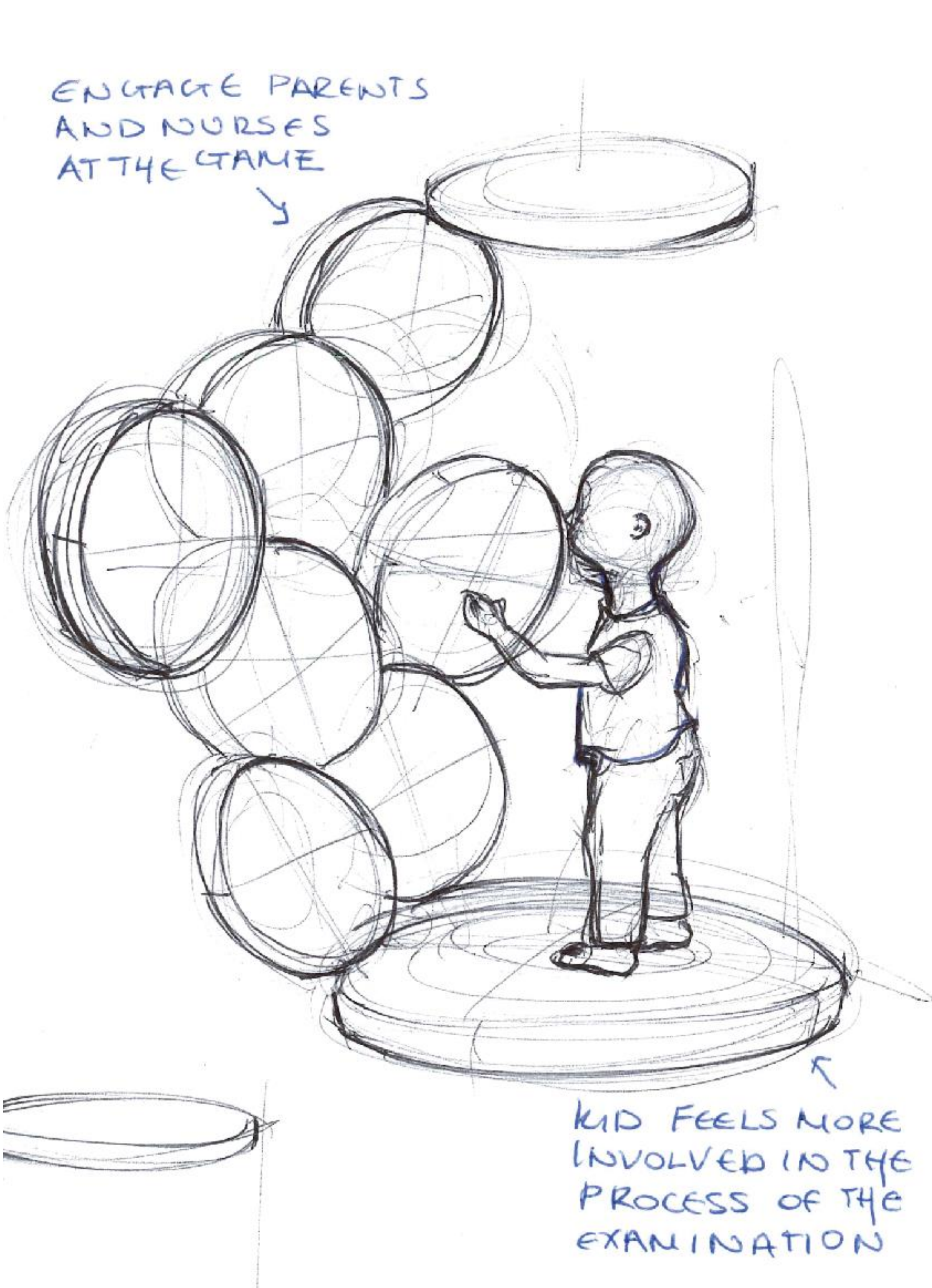


In this version, the kid could press a heart and listen to its heart rate and then lighting would also indicate its height.



The design idea that I being presented next is a combination of the drum sets and the previous device. In this one the height and the weight are being measured and the heart rate button is hidden, so the kid has to guess and find which one it is. Moreover the oxygen and the temperature would be appeared in different buttons and with different sounds,

The platform is also wheelchair accessible for the disabled patients although in this case the measurements would not be reliable.



After consideration, in the final form there will not be any signs of heart rate or oximeter, since the young patient might get nervous since it does already know that it will have a surgery afterwards. As a consequence the child is calmer and not getting any extra stress in case something is going wrong with its results.

Moreover, the large scale of the device allows parents and medical staff to take part in the game as well, so as to help the child in case is too high for him.

Figure 91: Interactive game final design

10.4. SENSORS USED

In this chapter we will discuss the parts used and their purpose.

10.4.1. Balance

The first and biggest "sensor" we use is the balance which we use to determine the weight of the child. The balance will be adapted in the floor of the game, to have a better accuracy and easy usage, the balance won't be visible because of the fact that it is built into our system. The weight of the platform will be deducted from the total weight in the moment of measuring the weight. The data will be requested and sent over Bluetooth to the application, which will then process it and preform the needed calculations (like the deduction of the weight of the platform from the total weight). Hereafter the application will display the weight on the screen of the tablet which is used and connected to the system. The weight in despite to the fact that it can be real time monitored will be only saved and requested when the nurse assigns this measurement. The reason behind it is because of the dynamic of the child who is carefree playing can influence the measurement (like in example jumping to hit a higher button), which is not desired. The balance which we are going to use and the reason behind it can be found in the state of the art of this report under conventional sensors and weight sensors as subchapters.

10.4.2. Distance sensor

In this project measuring height (which is also a common measured vital sign) was highly desired.

We could measure height in two different ways: or we use an infrared ranging sensors like the *IR Sensor GP2Y0A02YK* or we use ultra-sonic sensors like the HC-SR04. Both have their advantages and disadvantages, we chose the ultra-sonic distance detection.

Our decision was firstly based on the fact that IR ranging sensors can be influenced by light and sometimes even colour of the object. The second reason behind our decision was the detection range of objects that the sensors (within a certain financial budget) provide.

The working principles of the IR ranging sensors is shortly explained in the Appendix D: IR ranging sensors working principles. Further a short explanation of the ultra-sonic sensor will follow.

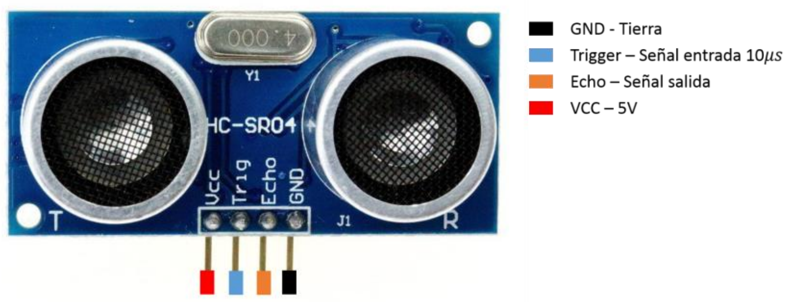


Figure 92: Ultra-sonic sensor HC-SR04

The upper sensor is the ultra-sonic HC-SR04, which is used to determine the height of the child.

An ultra-sonic sensor works based on sound (waves which are transmitted in a medium). Basically we can calculate the height of the child by determining how far from the sensor the child is, and deducting this distance from the height on which the sensor is placed.

The basic technical characteristics will be centralized and explained (How the sensor works will be explained in the Appendix C: Ultra-sonic sensor). First there will be a part about how the connection of this sensor was established in our circuit, which will be more detailed explained in the circuit chapter 11.7 of this report.

The HC-SR04 has 4 pins:

- Vcc: This pin is connected to the 5V output of the arduino itself. Which is optimal since the working dc voltage of this sensor is 5V.
- Trig: This is the trigger pin which is connected to the digital I/O pins of the arduino (details in chapter 11.7 Circuit).
- Echo: This is the echo pin which is also connected to the digital I/O pins of the arduino.
- GND: This pin is connected to the ground of the arduino microcontroller.

The working current of this sensor is 15mA.

The sensor is placed in the upper platform of the game with the approximate height of 1.60m (counted from the lower platform).

10.4.3. Capacitive sensor

This will be the sensing parts of our system which will actually “feel” whether the button is touched or not. Since the sensor itself needs to be conducting we have chosen for a high sensibility so that a top coat of a more pleasant to touch material can be applied.

Here we don’t use an extra sensor, we use an arduino library and his capability of reading in values like charge for example. We have written a short explanation on how this works in our system which can be found in the Appendix E: Capacitive sensors working principles.

10.5. MICROCONTROLLER

“A microprocessor on a single integrated circuit intended to operate as an embedded system. As well as a CPU, a microcontroller typically includes small amounts of RAM and PROM and timers and I/O ports.

An example is the Intel 8751.” [55]

The choice to use a microcontroller was made due to the fact that it is relatively simple to program it so that it “controls” the system and provide the basic functionality of a computer without having the high power consumption and usage of space from it. The microcontrollers are dedicated to preform one task (execute one programmed script), which is optimal for our system. Since we want to create a relative mobile system it needs to be low power, and powered by batteries.

This leads to a choice between two very good micro controllers which each serves its own purpose.

10.5.1. Raspberry Pi

The Raspberry had its early concepts (pre-production) laid in 2006 and it was based on a microcontroller namely Atmel ATmega644.

The Raspberry Pi is in fact a small computer, this leads it to be able to process high amount of data simultaneously and fast. In general a raspberry pi is powerful, has a lot of memory and storage capabilities. However it has limited pwm[19] outputs and ADC also the power consumption is higher than that of the arduino.

The detailed technical specifications can be found in the datasheet which will be included in the annex.

[19] PWM (PULSE-WIDTH MODULATION): IS A MODULATION TECHNIQUE USED TO ENCODE A MESSAGE INTO A PULSING SIGNAL. ALTHOUGH THIS MODULATION TECHNIQUE CAN BE USED TO ENCODE INFORMATION FOR TRANSMISSION, ITS MAIN USE IS TO ALLOW THE CONTROL OF THE POWER SUPPLIED TO ELECTRICAL DEVICES.

Figure 93: Raspberry Pi 2, Model B

10.5.2. Arduino Mega

The arduino mega is a microcontroller which is easy to use, it also has its own arduino software IDE. This makes it simpler to program for this microcontroller. Another plus point is that it has 15 pwm pins which we can use. The power consumption of this micro controller is rather low, and it can be powered by a renewable 5V block battery.

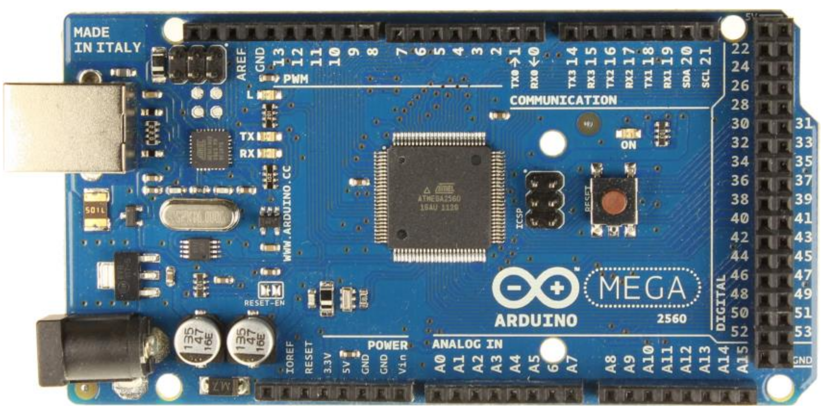


Figure 94: Arduino Mega 2560

10.5.3. Comparison

	Raspberry Pi B	Arduino Mega2560
Chip	Broadcom BCM2836 SoC	ATmega2560
Core architecture	Quad-core ARM Cortex-A7	8 bit RISC
CPU	900MHz	16MHz

GPU	Dual Core VideoCore IV® Multimedia Co-Processor	-
Memory	1GB LPDDR2	256kbyte
Operating System	Linux based (boots from SD)	Arduino Software IDE
Dimensions	85 x 56 x 17mm	101.5 mm x 53.34mm
Power	5V, 2A	2.75 approx.
Ethernet	10/100 BaseT Ethernet socket	-
Video output	HDMI (rev 1.3 & 1.4)	-
Audio output	3.5mm jack, HDMI	- (pwm)
USB	4xUSB 2.0	1
GPIO	40 pin (from which 27 GPIOpins)	54
PWM	0	15
Memory card slot	MicroSDIO	-

Table 28: Comparison microcontrollers

After comparing these two microcontrollers, the decision was made to use the arduino. These due to the fact that it has pmw pins which we are going to use, another reason is the low power consumption which will increase life of the game without changing batteries. The extra plus that we have is that this microcontroller doesn't use an operating system which we need to install, and that we have experience with working with the arduino.

10.6. CIRCUIT

All the parts interconnected resulted in Figure 86 which is the schematic of the physical system. This is the circuit which is going to build into the game that is visualized int 11.3 Design of the game chapter. The balance is not included in this part simply because it isn't connected to each other apart from being in the same space physical. The data transmission between the balance and the mobile application will be trough Bluetooth, and separately from this circuit which also will transmit data through Bluetooth connection.

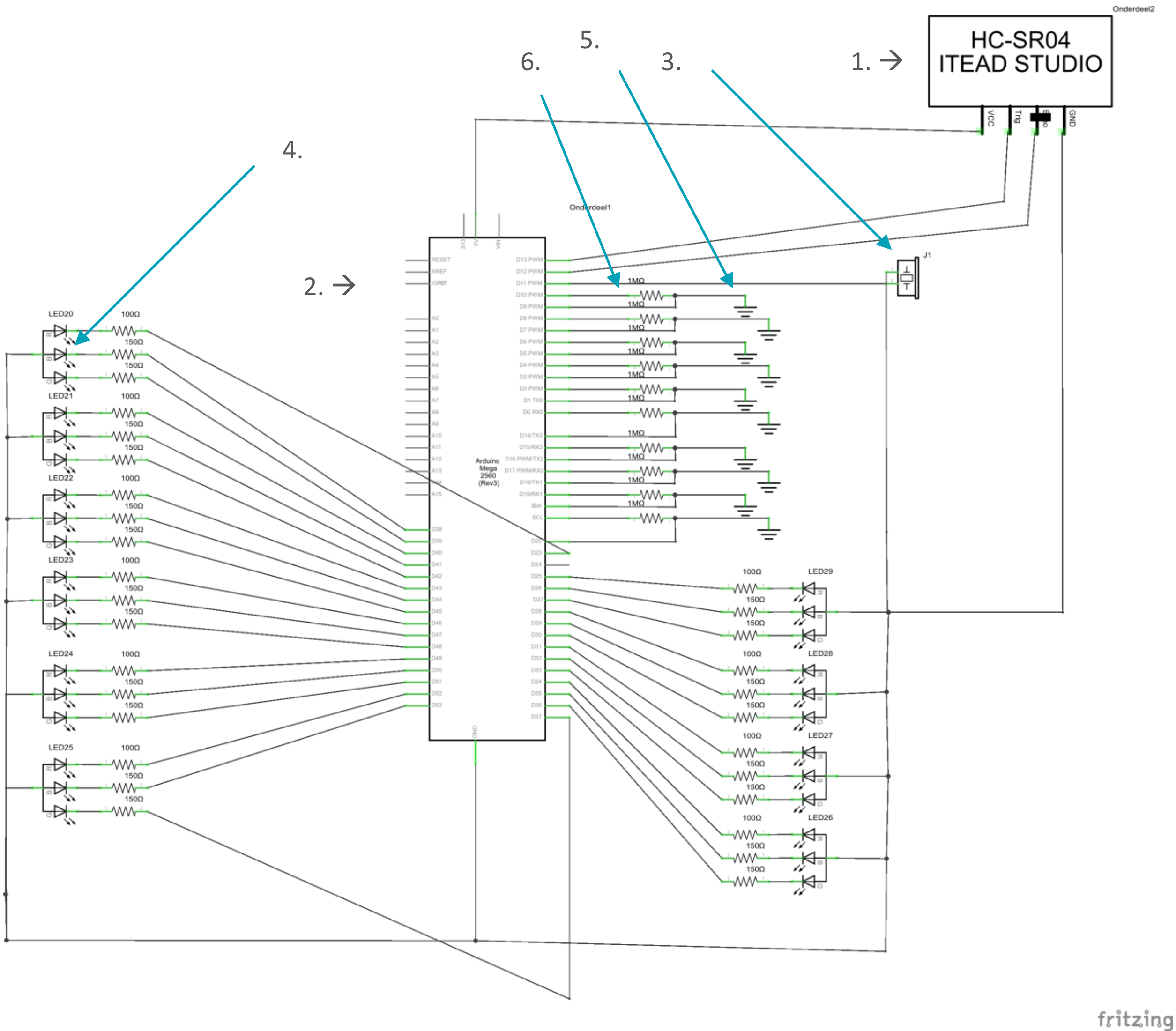


Figure 95: Full system schematic

1. This represents the ultra-sonic sensor and its connections.

The working principles are discussed in 11.4.2 chapter, as shown on the picture the vcc pin is connected to the 5V of the arduino. The ground is connected to the gnd pin of the sensor. The trig pin is connected to the 13th pwm pin and the echo pin is connected to the 12th pwm pin of the arduino board.

2. This represents the microcontroller which in our case is the arduino mega 2560 with its connections.

3. This represents the buzzer which is responsible to play a sound, with its connections.

The buzzer that is here used is an electromechanical component which is used to make sound. Inside the buzzer is a coil of wire and a small magnet. When current flows through the coil, it becomes magnetized and pulls towards the magnet, which on its turn create a tiny "click" sound. When this is done thousands of times per second, tones are formed. Different frequencies (speed of current pulses) produce different sounds.

4. This represents the RGB led which is responsible to lighten up the buttons, with its connections.

RGB leds are leds that can produce white light, this by means of mixing red, green and blue color together in certain proportions. Here they are used to produce a multi-coloured system, since we can control the amount of color distribution within a led, we can create almost any color.

The leds we are using are anode based which means they are connected to the ground and receive their value (current) from the arduino. The ground pin of the led is connected directly to the ground of the system (from the arduino). Each color has its own operative voltage the red part has a typical working voltage of 2.2V with the supply of 20mA (arduino I/O pin output current) we need an 110Ω resistor (the closes by is 100Ω which we used). ➔ V/I=R → 2.2V/0.02A=110Ω

The green and blue parts have the same working voltage of 3.2V typically which leads us to a 160Ω resistor needed (150Ω closes by which is used).

The resistor has the function to limit the voltage and the current going to the led but also prevents the led from draining infinitive current from the system.

5. This represents the touch sensor (the outer end which needs to be touched, with its connections.

6. This represents the resistor which is connected in between the send and receive pin of the arduino.

11. Conclusion

The project’s outcome consists of 3 parts, the first one is a mobile application with a database to store the patient's information and measurements. This application is created based on Bluetooth low energy communication, which allows it to change the connected wearable devices and with small adaptations it will be functional. Even though the smart band has been proven to be not sufficiently accurate and not suited for this project. This market is rising and soon there will be a smart wearable technology that can fulfil the requirements.

The second delivery is the design for the interactive game represented in a 3D Cad model. And the interactive game itself (the circuit and programmed code) is the third delivery. When the game would be produced for testing implementing this circuit we strongly believe that the main objective, which is to decrease child's anxiety, will be reached.

Overall this is a futuristic project which can have a great value to the hospitals due to the fact that it can be implemented in every procedure which needs to measure children's vital signs. Also relieving the stress of not only the child but also the relatives and it also lightens the chores of the nurses by decreasing the daily struggle of constructively collecting the measurements. Since this solution will decrease anxiety which influences the accuracy and reliability of the measurement, this project will also improve the accuracy and reliability which are two very important factors.

Another element is the provision of the chance to monitor the vital signs in real time, instead of a onetime measurement. This can be significant with cases that heavily depend on vital signs changes.

At last it is worthy of mentioning that decreasing children's anxiety will result in decreasing their fear of visiting hospitals. This in turn can considerably increase their global health level.

12. Further Steps

Although this project has come to an end, there are a few recommendations we wanted to include if this project would be continued.

Since the smart wearable wristband we chose wasn't suited for this project, the measuring of vital signs (Heartbeat, temperature and oxygen saturation) is not possible right now. So one of the further steps would be too find a smart wearable wristband that will suit this project or to create a sensor based circuit that will be able to measure the vital signs. If it is chosen to create a circuit the fact that the application communicates over Bluetooth low energy should be taken into account. However the accuracy of measurement procedures should increase (or at least remain at the same level), thus testing on a broad public is recommended.

We provided a 3D cad for the design of the game, the next step with that would be to produce it and build the prototype by assembling the product with the hardware circuit we provide.

This projects main goal was to decrease anxiety of children during these measuring procedures, so testing the decrease of fear, stress and negative behaviour with the build prototype would be really important. Also testing the reaction of disabled children would be a plus.

The application could be tested on medical nursing staff more to see if the results we had were representative in general, but this is a minor recommendation.

13. Acknowledgements

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14. Table of figures

15. Table of tables

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17. Appendix

A. BLUETOOTH SMART

Bluetooth Low Energy- also called Bluetooth Smart is a new version of Bluetooth protocol in version 4.0. Primary goal for creation of a new version of well-established on the market Bluetooth standard was rapid development of ideas involved with Internet of Things (IoT) [P]

Bluetooth Smart is power efficient technology what makes it excellent solution for devices that has to work for long time being powered with small batteries. This fact tremendously increased popularity of new Bluetooth standard for fitness and health devices.

Comparison of classical Bluetooth and Bluetooth Low Energy is presented in Table D 29, 30, 31 and figure 87.

	Classic Bluetooth	Bluetooth SMART
Data payload	2Mbps	~100kbps
Radio frequency	2.4GHz	2.4GHz
Range	10- 100m	10-100m
Active slaves	7	Unlimited
Security	56 to 128 bit	128 bit
Latency	>100 ms	<6 ms
Sleep current	-	0.78uA
Awake current	>20 mA	4.5mA

Table 29: Comparison classic and low energy Bluetooth technology

Bluetooth Low Energy communicates with devices using Profiles, Services and Characteristics in the form as presented in the Figure 87.

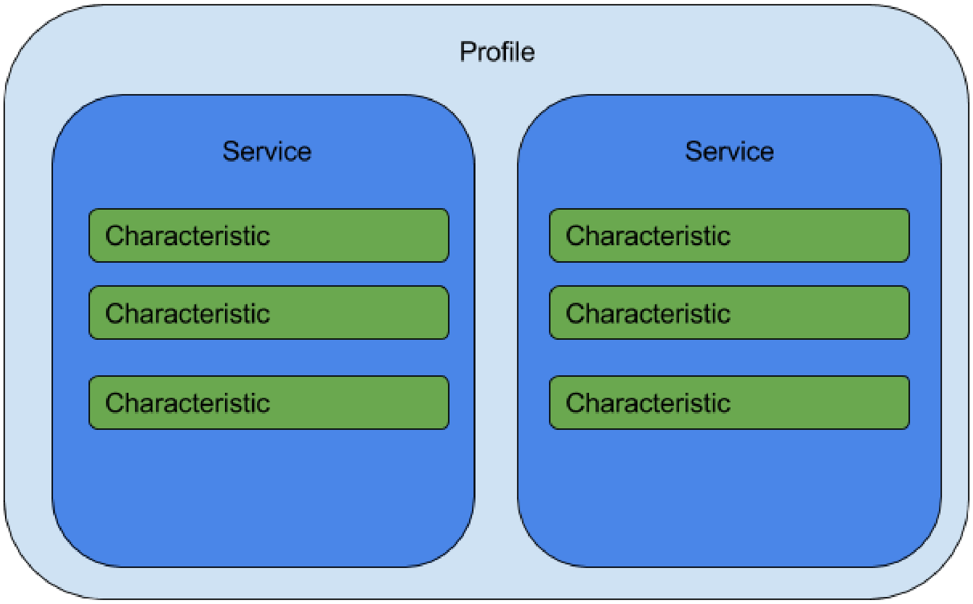


Figure 96: Bluetooth Smart data architecture

In order to get desired characteristic, application needs to connect to the service and retrieve value of the characteristic.

Having provided standard set of services and characteristic that satisfy most, if not all of required kind of information, Bluetooth organization has allowed application to be independent on specific Bluetooth peripherals. Instead, application can communicate with all measuring devices that satisfy Bluetooth Smart standards.

In the mobile application being described in this paper we have used services presented in the Table 30. And characteristics- present in the Table 31.

Service name	Service UUID
Heart rate monitor	0000180d-0000-1000-8000-00805f9b34fb
Health thermometer	00001809-0000-1000-8000-00805f9b34fb
Battery service	0000180f-0000-1000-8000-00805f9b34fb
Pulse oximetry monitor	0000181d-0000-1000-8000-00805f9b34fb
User data (height)	0000181c-0000-1000-8000-00805f9b34fb
Weight	0000181d-0000-1000-8000-00805f9b34fb
Optical wavelength service	902dcf38-ccc0-4902-b22c-70cab5ee5df2

Table 30: Services used in the mobile application

All services, except the lowest one, are standard ones for Bluetooth Low Energy protocol. The bottom one, in turn, is dedicated solely for the Angel Sensor. Service BLOOD_OXYGEN provides the same functionality like PULSE_OXIMETRY, however Angel Sensor does not support PULSE_OXIMETRY service.

Characteristic name	Characteristic UUID
Heart rate measurement	00002a37-0000-1000-8000-00805f9b34fb
Temperature measurement	00002a1c-0000-1000-8000-00805f9b34fb

Battery level	00002a19-0000-1000-8000-00805f9b34fb
Pulse oximetry measurement	00002a5f-0000-1000-8000-00805f9b34fb
Weight measurement	00002a9d-0000-1000-8000-00805f9b34fb
Height measurement	00002a8e-0000-1000-8000-00805f9b34fb
Blood oxygen measurement	b269c33f-df6b-4c32-801d-1b963190bc71

Table 31: Characteristic used in the mobile application

Like in case of services, also here- the last characteristic that is part of Optical wavelength service- Blood oxygen measurement- is not element of Bluetooth Smart standard but special identificator for the Angel Sensor.

B. MOBILE APPLICATION CODE FRAGMENTS

This appendix contains parts of code of the most essential classes used in the application.

BleAdapterService- service responsible for management of Bluetooth Low Energy connections.

```
 public  boolean connect(final String address){
     if(mBluetoothAdapter==null || address==null){
        return false;
     }
   final BluetoothDevice device=
mBluetoothAdapter.getRemoteDevice(address);
     if(device==null){
        return false;
     }
     mBluetoothGatt=device.connectGatt(this, true, mGattCallback);
     return true;
  }
```

mGattCallback- is a function that is called when the connection is established. All Bluetooth Low Energy functionalities are asynchronous.

```
private final BluetoothGattCallback mGattCallback=new
BluetoothGattCallback() {
     @Override
     public void onConnectionStateChange(BluetoothGatt gatt, int status,
int newState) {
        if(newState== BluetoothProfile.STATE_CONNECTED){
```

```
            mBluetoothGatt.discoverServices();
            Message msg=
Message.obtain(mActivityHandler,GATT_CONNECTED);
            msg.sendToTarget();
}
else if(newState==BluetoothProfile.STATE_DISCONNECTED ||
newState==BluetoothProfile.STATE_DISCONNECTING){
            Message msg=
Message.obtain(mActivityHandler,GATT_DISCONNECT);
            msg.sendToTarget();
      }
}
@Override
public void onServicesDiscovered(BluetoothGatt gatt, int status) {
         //Enable local notifications
       for(BluetoothGattService s:gatt.getServices()){
            for(BluetoothGattCharacteristic
c:s.getCharacteristics()){
             gatt.setCharacteristicNotification(c, true);
               //Enabled remote notifications
               BluetoothGattDescriptor desc =
c.getDescriptor(BleDefinedUUIDs.Descriptor.CHAR_CLIENT_CONFIG);
               if(desc==null){
                  Log.d("NOTIFICATIONS","Cannot set notifications for: "+c.toString());
                  continue;
               }
               desc.setValue(BluetoothGattDescriptor
.ENABLE_NOTIFICATION_VALUE);
               gatt.writeDescriptor(desc);
               Log.e("NOTIFICATIONS","Notifications enabled");
            }
```

```
        }
        Message msg=Message.obtain(mActivityHandler, GATT_SERVICES_DISCOVERED);
        msg.sendToTarget();
    }
@Override
public void onCharacteristicRead(BluetoothGatt gatt, BluetoothGattCharacteristic characteristic, int status) {
        if(status==BluetoothGatt.GATT_SUCCESS){
            Log.i("CHARACT_READ","Ble service OnCharacteristicRead, success");
            Bundle b=new Bundle();
            b.putString(PARCEL_UUID, characteristic.getUuid().toString());
            b.putByteArray(PARCEL_VALUE, characteristic.getValue());
            Message msg=
Message.obtain(mActivityHandler,GATT_CHARACTERISTIC_READ);
            msg.setData(b);
            msg.sendToTarget();
        }
    }
    @Override
    public void onCharacteristicChanged(BluetoothGatt gatt,
                BluetoothGattCharacteristic characteristic)
    {
        Log.e("BLE!!","Characteristic changed!");
        Bundle b=new Bundle();
        byte[] rawValue = characteristic.getValue();

if(characteristic.getUuid().toString().equals(BleDefinedUUIDs.Characteristic.HEART_RATE_MEASUREMENT)){
            int index = ((rawValue[0] & 0x01) == 1) ? 2 : 1;
            // also we need to define format
            int format = (index == 1) ? BluetoothGattCharacteristic.FORMAT_UINT8 : BluetoothGattCharacteristic.FORMAT_UINT16;
```

```
            int intValue = characteristic.getIntValue(format, index);
            b.putInt(PARCEL_VALUE, intValue);
        }else
if(characteristic.getUuid().toString().equals(BleDefinedUUIDs.Characteristic.PULSE_OX_MEASUREMENT)
){
            int format = BluetoothGattCharacteristic.FORMAT_SFLOAT;
            float floatValue = characteristic.getFloatValue(format, 1);
            b.putFloat(PARCEL_VALUE, floatValue);
        }else
if(characteristic.getUuid().toString().equals(BleDefinedUUIDs.Characteristic.WEIGHT_MEASUREMENT)){
            int index = ((rawValue[0] & 0x01) == 1) ? 2 : 1;
            int format = BluetoothGattCharacteristic.FORMAT_UINT16;
            int intValue = characteristic.getIntValue(format, index);
            b.putInt(PARCEL_VALUE, intValue);
        }else
if(characteristic.getUuid().toString().equals(BleDefinedUUIDs.Characteristic.TEMPERATURE_MEASUREM
ENT)){
            int index = ((rawValue[0] & 0x01) == 1) ? 2 : 1;
            int format = BluetoothGattCharacteristic.FORMAT_FLOAT;
            float floatValue = characteristic.getFloatValue(format, index);
            b.putFloat(PARCEL_VALUE, floatValue);
        }else {
            //TODO: format temperature measurement
            int intValue=-1;
            if(rawValue.length > 0) intValue = (int)rawValue[0];
            if(rawValue.length > 1) intValue = intValue + ((int)rawValue[1] << 8);
            if(rawValue.length > 2) intValue = intValue + ((int)rawValue[2] << 8);
            if(rawValue.length > 3) intValue = intValue + ((int)rawValue[3] << 8);
            b.putInt(PARCEL_VALUE, intValue);
        }
        b.putString(PARCEL_UUID, characteristic.getUuid().toString());
```

```
            Message msg=Message.obtain(mActivityHandler,GATT_CHARACTERISTIC_READ);
            msg.setData(b);
            msg.sendToTarget();
        }
        @Override
        public void onReadRemoteRssi(BluetoothGatt gatt, int rssi, int status) {
            if(status==BluetoothGatt.GATT_SUCCESS){
                Bundle b=new Bundle();
                b.putInt(PARCEL_RSSI,rssi);
                Message msg=Message.obtain(mActivityHandler,GATT_REMOTE_RSSI);
                msg.setData(b);
                msg.sendToTarget();
            }
        }
};
```

C. ULTRA-SONIC SENSOR WORKING PRINCIPLES

A short explanation about the working principles of the ultra-sonic sensor will follow.

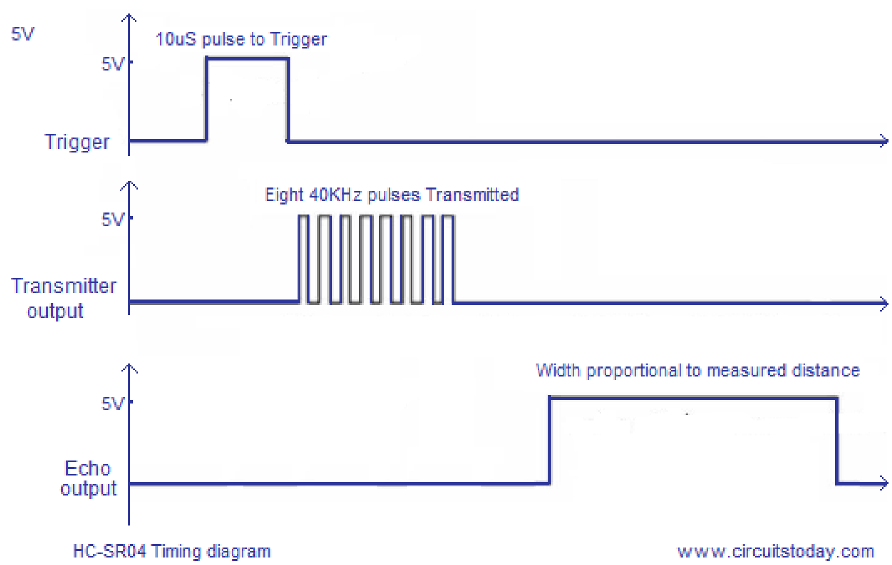


Figure 978: HC-SR04 working diagram

The three graphs above represent the actions and reactions of the sensor. The distance calculations are based on sound waves and the reflection of them, so first off the sensor needs to send a sound wave. If we apply 5 volt of dc voltage during 10 micro seconds (called a pulse) we will trigger the sonic burst (8 short 5V pulses after each other which we call an 8^{th} cycle sonic burst) from the module sent forward. When the burst is complete the sensor will wait for response. When the sound wave hit an obstacle (in our case a child) it will reflect from it and forward to the sensor, so the sound wave which the sensor sends out will return to the sensor if an object is placed in range. Since the sonic burst was completely sent the echo pin will be placed on high, from the moment the echo arrives the echo pin will change to low. This will be interpreted by the module and we can read out the time it took for the signal (the sound wave) to return. From the time in between sending out the trigger signal and receiving an echo signal we can calculate the distance from the sensor to the object. To get the distance in centimetres we need to apply following formula: µs / 58 = distance in centimetre.

The first parameter is the time it took to get an echo. The 58 value we gather from the fact that it takes 58 µs for a sound wave to reach a distance of 1 cm and then reflect and be received by the sensor. (speed of sound is 340.29m/s, since the wave travels 2cm (1cm to the object and one back to the sensor) → 0.02m/340.29m/s ≈ 58µs → It takes the signal 58 µs to travel to an object distanced 1cm from the sensor and back)

Distance in inch: µs / 148

Distance in m = high level time of echo pin * velocity (340M/S) / 2;

D. IR RANGING SENSOR WORKING PRINCIPLES

The Sharp IR Range Finders works by the process of *triangulation*(a technique for establishing the distance between any two points, or the relative position of two or more points, by using such points as vertices of a triangle or series of triangles, such that each triangle has a side of known or measurable length (base or base line) that permits the size of the angles of the triangle and the length of its other two sides to be established by observations taken either upon or from the two ends of the base line.). A pulse of light (wavelength range of 850nm +/-70nm) is emitted and then reflected back (or not (completely) reflected at all in some circumstances). When the light returns it comes back at an angle that is dependent on the distance of the reflecting object.

Triangulation works by detecting this reflected beam angle - by knowing the angle, distance can then be determined.

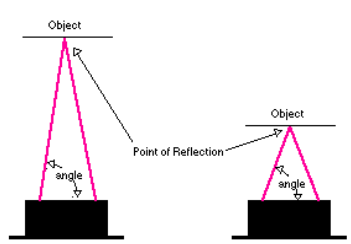


Figure 98: IR triangulation with one known angle

Figure 99: IR ranging sharp GP2Y0A02YK

E. CAPACITIVE TOUCH SENSING WITH AN ARDUINO

The working Principe is simple, human body caries electrical charge, the connection with aluminium and human skin will form a capacitor. How higher the capacitivety how more charge it can store which also results into a longer time to charge. The arduino is basically measuring the time it takes the connection to the digital pin (with aluminium attached in our case) to charge. This time will be interpreted and further processed the end product we will get is the estimated capacity. Between the send and receive pin we place a resistor to adjust the sensitivity of the sensor given the fact that we use an arduino mega a 1MΩ resistor would be sufficient to read a touch of a button and still have a high value (1000) but since we are using a high amount of these sensors, the sensitivity can drop. If a higher sensitivity would be needed simply changing the resistor between the send and receive pin (where the aluminium is connected to) from the arduino would be sufficient. The system right now can have a “coat” (top layer of plastic for example) around half a cm to still be able to receive the signal.

F. MANUAL

1. Overview

The application Fun Weight enables a nurse to preview patients, their measurements, obtain measurements and add new children to the patient database. All information that you need to become accustomed with the Fun Weight application are included in this manual. In case of any doubts or suggestions, contact with the developer: kubawalczak@gmail.com

ATTENTION! Application is dedicated only for the tablets with Android operating system

2. Installation and configuration

In order to install the application Fun Weight, you need to follow below steps:

- ~ Enable installation from unknown sources (Settings->General->Security and tick checkbox Unknown sources see figure on the right)
- ~ Download .apk file that contains the application
- ~ Open the .apk file and follow the instructions

If the application will be installed correctly, you will be able to find icon on the left among your other applications.

3. Run the application

In order to start application, follow below steps:

- ~ Open list of application in your tablet. In Android tablets, it is usually denoted by  sign in the left bottom corner of the main screen.
- ~ On the list of your application find icon of the application that looks like this one .
- ~ Tap the icon and wait for opening the application

Signing in

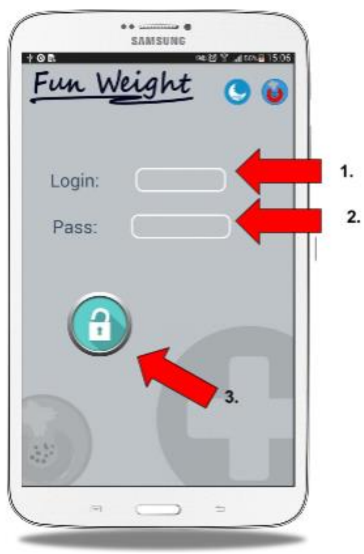


Figure 100: Sign in with explanation

To use the application, you need to sign in, because access is allowed only for authorized staff. When you already open the application, you will see login screen similar to that one which is shown on the right. In order to log in tap on the white rectangle on the right of Login label (1) and input your username. Then tap the white rectangle next to the Pass label (2) and type your password. Password always consists only of the numbers.

ATTENTION! Username and password are information that enables proper authentication of the user. <u>Do not share your username nor password!</u>

When appropriate username and password are already input, click the button (3) to log in.

Preview of the patients

After signing in, you will see a view like this on the left. To find patients with a specific family name:

~ input a family name in the text box (1)

~ click smaller Find button with a magnifier (2)

Afterwards, list of patients with matching last name will be presented.

ATTENTION! Application will return patients with a family name <u>exactly the same</u> as input in the text box. Application <u>do not</u> search for similar family names.

If you want to browse the whole database of the patients, tap button (3) and leave the text box above (1) empty.

Afterwards, list of patients will be presented.

ATTENTION! To find patients Internet connection is indispensable!

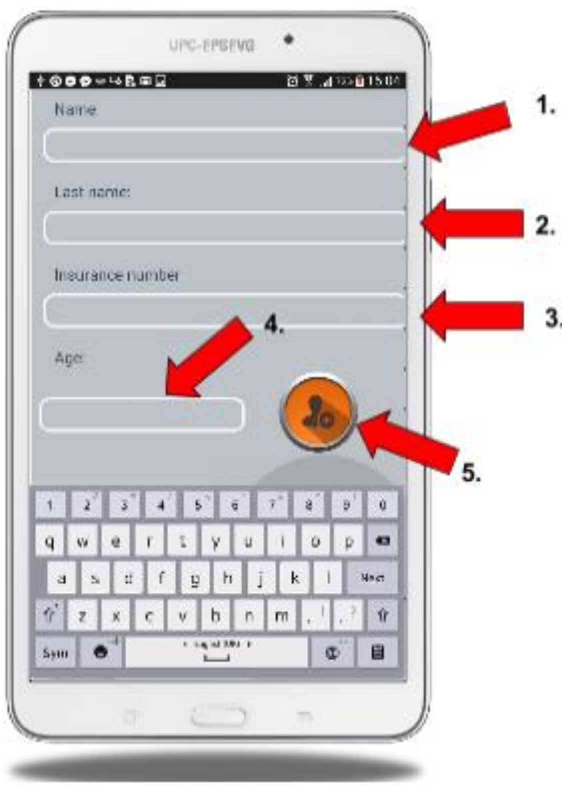
The list of the patients looks like in the figure on the right hand side. The list is sorted in alphabetical ascending order by family name **(A->Z)**.

This view provide patient's name, family name and insurance number that enables identification of the patient in case of ambiguous situation. To open the patient screen type on the desired patient in the list.

Addition of the patient

If you want to add a new patient into database, the application provides such possibility for a nurse. To add a patient click *Add* button (1) in the main screen like in the figure on the right. Then the screen similar to that on the left below will be shown.

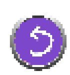
ATTENTION! To add a patient Internet connection is indispensable!



To add a patient all text boxes need to be filled.

~ tap on the *Patient name* text box (1) and input a patient's name

~ tap on the *Patient family name* (2) and input patient's family name

ATTENTION! Remember to start both name and family name with a capital letters. To make a capital letter tap icon  **on the left or right side of the screen keyboard.**

~ tap on Insurance number box (3) and input there the patient's insurance number

~ tap on the Age text box (4) and fill it with the patient's age

~ tap Add patient icon (5) in order to add patient

ATTENTION! Remember! Insurance number should be input with the format appropriate for your country.
When all text boxes are already filled, click *Add* button (5) to add a patient into database.

Connecting to measuring device

After choosing desired patient from the list (To present the list of the patients, see part Preview of the patients), you will see view like this on the right. In order to preview measurements for chosen patient tap button (2). If you want to obtain measurements, firstly you need to connect to the measuring device, to do that click button (1). Afterwards you will see screen that enables you to connect to the device using Bluetooth (screen on the left).

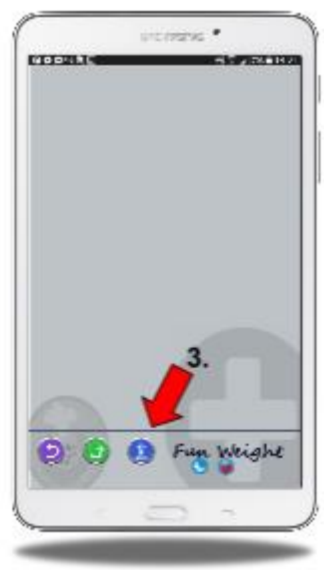
ATTENTION! Bluetooth has to be enabled before connection will be established.

To connect below steps:

~ click button on the measuring device to power it on
~ click button (3) with the logo of Bluetooth to start scanning for the Bluetooth Low Energy peripherals
~ choose desired device from the list of available peripherals

After that you will be notified with the screen that allows you to obtain measurements from the device.

ATTENTION! Before application will be notified with data from the measuring device, tap  **to establish connection with the Bluetooth Low Energy device.**



Obtaining measurements

To request the device for the measurements, firstly you need to choose the patient from the patient list (To present the list of the patients, see part Preview of the patients).

ATTENTION! To request for the measurements, Bluetooth connection is indispensable! To enable Bluetooth see Installation and configuration section.

(If you only want to browse patient's measurements, see the next section: **Preview of the patient's measurements**.)

After choosing the desired patient from the patient list, you will see the view like this one on the right hand side. Screen contains information about patient's name and family name.

ATTENTION! Opening patient screen can take a while because Bluetooth connection with the device needs to be established.

To obtain a particular measurements follow below steps:

- To get oxygen saturation of a patient tap O2 button (1)
- To obtain temperature level of the patient, click button with thermometer (2)
- To obtain heart rate of the patient, choose button with a heart (3)
- To obtain patient's mass of push the button with the scale (4)
- To get patient's height tap button with ruler (5)
- To request for all measurements at once, tap Start button (6)

Vital signs are presented in the circles on the left hand side of the each button. They are shown in the units according to below table

Value	unit
Temperature	oC
Oxygen saturation	%
Mass	kg
Heart rate	bpm

REMEMBER! Having obtained the measurements, save them to the database by clicking the button with a floppy disk (7).

Application will save the measurements automatically after pressing back button on the tablet .

ATTENTION! To save the measurements, Internet connection is necessary!

ATTENTION! For vital signs that has not been measured, default values will be assigned (zero).

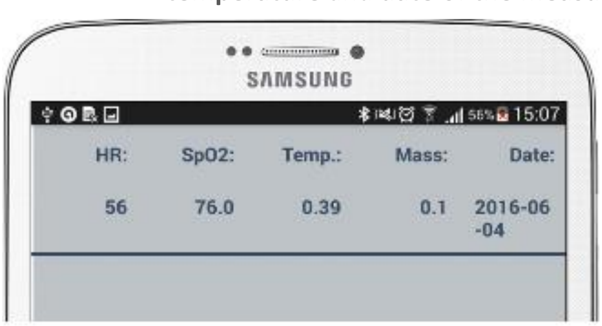
Preview of the patient's measurements

To browse the measurements of a patient only Internet connection is required. If Bluetooth is enabled you will see the view like in the section **Obtaining measurements**, if it is not, the screen like this on the left, will be shown to you. If Bluetooth is disabled, all buttons are inactive except the one that enables preview of the measurements for a patient. Click it (1) to browse the measurements of the patient.

ATTENTION! Downloading measurements can take a while!

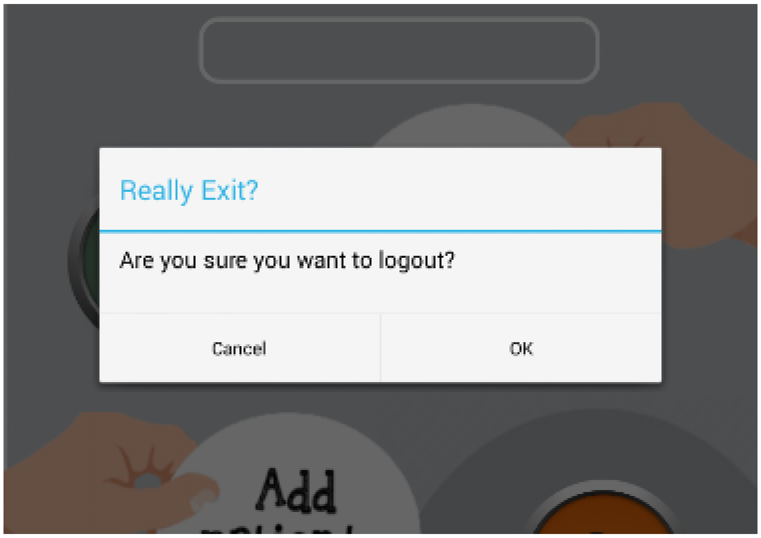
You can browse patient's measurements also without connecting to the measuring device, to do that, having chosen desired patient choose Preview button (2) there - see image below.

List of measurements looks like the figure below. Each measurement contains information about **heart rate, oxygen saturation, weight, temperature** and **date of the measurement**.



ATTENTION! Having finished all activities, remember to logout from the application!

In order to logout, click button in the right bottom corner of the table until you will be prompted with the information about logging out. Then click *OK* to log out.



Back button

In order to return to previous view tap tablet button in the right bottom corner or button in the left upper corner of the application.

Troubleshooting

- List of patients/measurements is not loaded.

There might be two reasons for such behaviour: either database is empty or data was not downloaded correctly.

If the database is empty- add desired patient. Otherwise, tap back button and try to reopen the list. Applied database is free thus limited. If the database server does not start in the assumed time, application cannot retrieve data from it.

- Cannot connect to the measuring device/ buttons for obtaining measurements do not work

Check if the device is turned on. If not turn it on. If so, check if your tablet has Bluetooth connection enabled (to enable Bluetooth see section: *Installation and configuration*).If you have enabled Bluetooth after opening patient screen (that allows you to perform measurements), tap back button and reopen the patient screen. Establishing connection can take a while.

- Cannot obtain some of the measurements

If you have clicked plenty of times buttons requesting for the measurements, it might happen that application cannot run more threads. To fix it, tap back button and reopen the view.

- Measurements are not displayed in the screen

There can be several reasons for that. The most probable is that measuring device does not send notifications about vital signs measurements. Check instruction for measuring device in order to enable device.