Trip Saver

Final report Engineering Design (4WBB0)

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Table of Contents

Group effectiveness

The majors of the group members are: Mechanical Engineering, Build Environment, Industrial Design, Psychology & Technology, Mathematics & Informatica and Applied Physics. These majors resulted in a good combination of the more creative solution thinkers and the technical solution thinkers. During the project this combination turned out to be really effective to develop a nice product. In our group most of us wanted to learn new things, which they hadn't learned during their own majors. Because of this the strengths and weaknesses of the group members were used to help each other. This resulted in a good and studious group dynamic.

Table 1: Strengths and weaknesses of the group

Strengths	Weaknesses
CAD, Python and Matlab	Planning
Program Languages	Taking initiative
Aesthetics	Aesthetics
Biology knowledge	Not sharing opinion
Video editing	Programming
Photography	
Getting things done	
Human aspect	
Basic understanding electronics	
Drawing	
Planning	

The table shows the strengths and weaknesses of our group. In our group one member had already some experience with DBL's and SSA's, so during the first weeks of this course he really helped us getting started with the course. One of the weaknesses of most group members was planning, so it was handy that one member organized all our tasks and reminded the group of the things that had to be done. Some of our strengths, such as CAD modeling, video editing, basic understanding of electronics, were useful to have. Because the group members with those skills tutored the other group members that wanted to learn, thus more people were able to work on one specific task and finish it in less time. Another asset of group was human aspect. The human aspect of the design was important to consider, since we designed a product for users. With the human aspect/user centered design focus we made sure that the people we are designing for are going to find our product useful. In the table you can see that some of the strengths and weaknesses can be canceled out, such as aesthetics and programming. This means that group members can help each other in these areas.

Design goal

The objective being addressed by this project design is to mitigate the danger of falling for elderly people so they can live more active and safer lives. Living a sedentary life comes with a large array of health risks (Volksgezondheid&Zorg, 2020) and, as people age, they often slowdown in their lives and when the danger of seriously injuring oneself in a fall comes along, this keeps people away from being active and healthy. As the world population ages, concerns like these will be more pressing and the costs of caring for the elderly rise. It is urgent this demographic becomes more healthy and more self-sufficient as time progresses so as to keep the healthcare system from being overburdened.

Falls are a big problem for elderly people. They can cause several injuries and are even source of death (CBS, 2019).

Falling can have multiple causes. Possible causes could be balances disorders, cognitive impairment, vision or muscle pain. As people age, their sensory system decreases. They become less sharp and the alertness decreases. This makes it hard to notice details. The shoe can make them more alert and notice things they oversee. This could be of great benefit as it prevents them from falling. This could build confidence and decrease the 'post fall syndrome' - the fear of falling which makes the elderly less active (Isaacs & Murphy). Also, it is of great benefit for economic costs caused by falls. Then, most importantly, it prevents injuries and short of death for people with these issues.

To prevent this, our design will alert the user of the obstacles in their walking path, to prevent falls before they happen. This device will hopefully inspire confidence in the elderly and allow them to be more active and mobile in their day to day lives and thereby live healthier and longer lives.

To achieve this goal our device will attach to the user's shoe and give them feedback when an obstacle is detected. This will require some basic electronic skills along with prototyping experience and programming knowledge. These were all skills identified as aptitudes of our group which bodes well for the project's outcome. While this product will certainly not appear unsightly, aesthetics is not a strong part of the design and thus the group's weakness in this area will not hinder the project's final goal.

The clear need in society to help the elderly stay healthier and active, paired with the main object - preventing them from doing so makes our design desirable indeed for helping solve these problems. With an interdisciplinary team, an innovative solution to the project's design problem will be found and a product worthy of being used will be created.

Functional design and solutions

For the functions of our design, we came up with the following MoSCoW list.

Table 2: The MoSCoW list

Must	Should	Could	Won't
Built within €70,-	Function autonomously or by interaction with the user	Look aesthetic	Check if laces are tied
Made for inhouse activity	Alert user in response to environment	Be chargeable	Have a shin bone sensor
Use sensor(s) and actuator(s)	Alert users of obstacles that could be tripped over	Let user change vibration intensity	Have a Bluetooth module
Light enough to not impede walking	Be wearable	Have an on/off switch	Offer sound feedback
Small enough to not impede movement	Offer haptic & visual feedback		Use a mobile app
Made from easy to purchase materials	Communicate between parts using radio		

The MoSCoW list shows what functions we wanted in our design. The first three musts were based on the assignment of this course. The other musts are based on our design goal - a device that alerts the elderly for obstacles in their way. Our design consists of a device strapped to the shoe which is connected to a bracelet. Because our device fits around the shoe, it is a must that it doesn't impede the walking experience of the users, this means the device should be light and small. Next to that, the device must also be made of materials that are easy to purchase, to stay within the budget and to get the materials in time. The device should also function autonomously by interaction with the user, since our user group, the elderly, have difficulties adapting to new devices. The design goal dictates that the device must alert the user for the objects in their way. This must be done via haptic feedback in the form of vibration and via visual feedback (a LED light) and not via audio feedback. This is the case, because data suggest that older adults are less adept at localizing sounds in space, specifically being prone to front/back localization errors. This difficulty in perception under noisy conditions demonstrates the importance of using cues in the visual modality instead of the auditory when presenting information in a potentially noisy environment." (Abel, Consoli, Giguere, & Papsin, 2000). Since elderly have a higher threshold for detecting an increase of vibration, we thought our design should consists of a vibrating bracelet, which would be a good way to make sure the user gets alerted by our output feedback (Salvendy, 2012). To transmit the information received by the ultrasonic sensor at the front of the shoe to the bracelet we should use radio communication, since it is less expensive than the Bluetooth alternative and meets all the requirements that we need (used on short distances: hand-leg, doesn't need a mobile app).

To achieve the functions for our device the following Solution Encyclopedia was made.

Table 3: Solution encyclopedia

Function	Solution
Detect obstacles	Ultrasonic sensor for detecting obstacles up to 450 cm
Alert user	Bracelet with light and vibration
Fit on all shoes	Elastic band around the shoe
Power source on shoe/bracelet	Rechargeable battery, replaceable battery
Works by interaction with user	On/off switch
Communicate between shoe and bracelet	Radio module
Splash proof	Encase electronics
Shock proof	Encase electronics

To detect objects in the way we will use an ultrasonic sensor, which is able to detect obstacles up to 450 centimeters away. To alert the user of the obstacles a bracelet was made which has output feedback in the form of vibration and light. To fit our device around the shoe an elastic band was used. For the power source of the device, we use a replaceable battery. For the user to interact with the device, we will use an on/off button to turn the device on and off. To make sure the shoe and bracelet can communicate with each other, to alert the user, we will use a radio module. In order to make our device splash and shock proof we will encase the electronics by 3D printing cases.

Design concepts

For the design concepts we came up with 3 different ideas. Those concepts are differentiated by the position of the sensor: on the front of the shoe, on the side or on the shoelace.

The electronics on the front of the shoe + Bracelet:

For the first design concept we made a band that would fit around the shoe, which would have the electronics at the front of the shoe. Next to that, the sensor at the front would be connected to a bracelet which would then alert the user for the obstacle. Looking at the MoSCoW list it became clear that this concept would probably not impede the movement and it would also be light enough to not impede the walking. We thought the design concept around the shoe wasn't looking that great, so when we would choose this concept, we would really have to investigate making it more aesthetically looking. After investigating we concluded that the bracelet would be a good way to alert the user. Since elderly have a higher threshold for detecting an increase of vibration, we thought the bracelet would be a suitable way to make sure the user responds to the output feedback (Salvendy, 2012). The bracelet would be a good addition to our design also because after testing response to haptic feedback we concluded that the response rate is higher when sent to your hand rather than your feet. This is because it is preferred to convey haptic feedback on the upper body instead of the lower body, since the sensitivity loss is bigger in the lower limbs compared to the upper limbs (Salvendy, 2012). Our biggest concern for this design concept was whether it would be possible to fit this prototype within the budget, since we need to make a connection between the feet and the bracelet.

Figure 1: The bracelet

Figure 2: The shoe band

The side sensor:

For this design concept we decided to use cardboard and glue it together to a box. This box would then be affixed to the side of the shoe. Some electronic components were used to simulate the sensors and controller board. These components were roughly the same size as the Arduino nano (the smallest board available). The small button in the front acted as a sensor. When looking at the MoSCoW list it became clear that this design concept would probably not impede walking and it would probably also be light enough to not impede walking. We did think it could be a little bit irritating that the box would be on one side, which could lead to some discomfort. The biggest drawback of this design would be that having the sensor on the side leads to changes in the efficiency of detecting obstacles, depending on the choice of shoes. This is caused by the change of angles when the user wears a low or a high shoe. When choosing this design, we would somehow have to implement how we want to tackle this problem. Another big drawback of this design concept was that we weren't sure obstacles would be detected because of the angle in which the sensor gets positioned. In this concept the output device would also be in the box on the side of the shoe. Since the sensitivity loss is bigger in the lower limbs compared to the upper limbs (Salvendy, 2012), we thought elderly would probably not be able to feel the vibration that well when the box is located on the side of the shoe.

Figure 3: Box on the side of the shoe

The shoelace:

For this design concept we sewed a little pouch that can be detached onto the shoe, using the shoelaces or the Velcro straps of the shoe. All the electronics are put in the pouch with the sensor at the front. A 'Must' on the MoSCoW list is that it doesn't impede walking or movement in any way. We thought this could be something that might not be met with this concept. We thought it wouldn't be comfortable to wear a box above your foot when walking. Thinking about aesthetics, we thought the concept did look okay, but it wasn't the best-looking idea. A difficulty of this design is that it can be hard to keep the sensor angled at the right position all the time. Because shoelaces are angled in different positions for different shoes. For example, a high shoe or a low shoe, it can be a challenge to keep the angle for the sensor angled in the right way (see fig. 5).

The biggest drawback of this design would be that you are only able to wear it when your shoe has laces or Velcro. When the user would be wearing flipflops or loafers the device can't be attached to the shoe.

Figure 4: Pouch on shoe lace

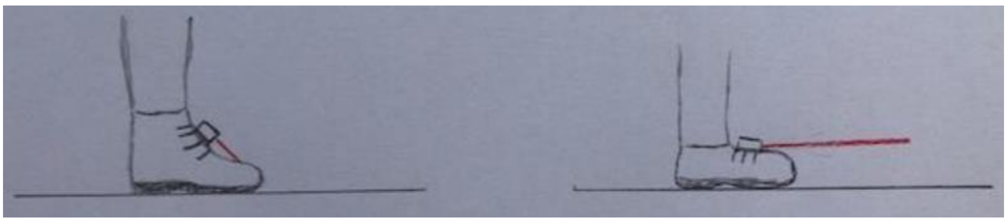


Figure 5: Sensor angled on shoe

Final design concept

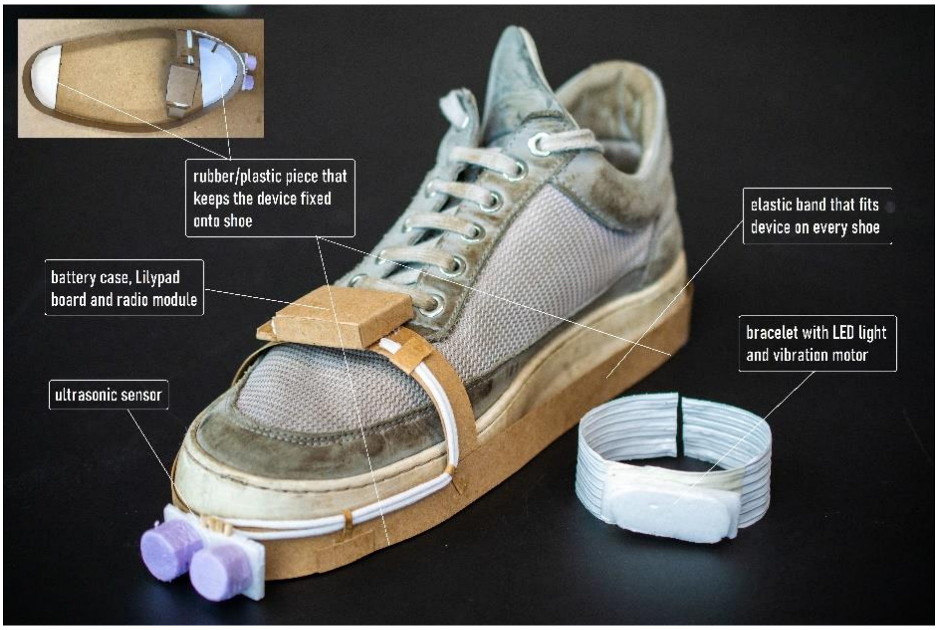


Figure 6: Preliminary Design

For our final design concept, we did a few adjustments on the initial one "The electronics on the front of the shoe + Bracelet".

With this design we can achieve that it fits on every shoe. Shoelaces are not needed and because of the elastic strap, all shoe sizes can fit this device.

We were concerned about the wires and the elastic strap because the wires can't extend like the elastic strap can. That's why we put the back case in the front so there would be minimal wiring. This way the wires will stay intact.

Then, we wanted to keep the front case as small as possible so now it is only occupied by an ultrasonic sensor. We 3D printed a case around it so it will be covered and protected. The ultrasonic sensor measures everything that is in front of the shoe, within a 450 cm distance.

The top part has been attached with rubber to the elastic strap and remains in place thanks to the 3D printed plastic case around it.

The cases around the electronics will make it splash proof as well.

The bracelet was the best for the feedback to the user. The population of elderly has a weak sensory system. The sensory system is better in the upper body, so we thought this positioning of the feedback is more noticeable for them. We placed a vibration motor in the bracelet to make the user aware. When the user is aware and wants to check if any feedback is received, there will be a light on the bracelet as well. This way the awareness process operates smoothly and is reliable. We also put an on and off switch on the bracelet to save battery life when the device is not in use.

Furthermore, all this material was easy to purchase so we were able to realize our project.

Technical specification

Defining the technical specifications was a critical part of the project. It helped us make sure that we used all possible resources and options to get the best device within the offered possibilities and, most importantly, that the product has most chances of working successfully. The specifications ensured that the product holds up to our expectations and were a guiding factor, which kept everything organized and coherent. The requirements the product must fulfill are the technical specifications. These requirements of the product consist of certain parameters the hardware and software should vindicate to. These parameters should and will be tested to make sure that the product will be more sufficient.

The main task of our product is to make sure elderly will be warned when they are about to trip into something. The product will fit on your shoe and measures the distance to objects in front of you. An elastic material will be used to strap the electrical components around the shoe and hold it in place. This material should be light, so the user feels comfortable wearing it. The distance will be measured by an ultrasonic sensor, which uses sound waves to locate a distant object. These sound waves will not be hearable by human ears. When the user is dangerously close to something, a signal will be sent to the wristband which will then notify you. The wrist band outputs feedback through a small vibration and a light to make sure the users does not misinterpret the vibration. These operations will all be working autonomously, due to an onboard micro controllers and RF transceiver modules, which can wirelessly communicate with each other.

The product works when the light is on, and a vibration is present when the sensor is close to an object. However, these notifications should stop after a while, for example, when the user is not moving closer to the object anymore. This will make sure the user does not get continually bothered by vibrations and light, when standing still close to an object, such as a kitchen counter.

With respect to the MoSCoW list, the product should be made for indoor and be light enough to not impede walking. This led to the usage of plastics and rubber for light and sturdy assembly. Plastics are in many situations. It is used in 3D printing and many synthesized materials are made from plastics, such as straps, buckles and more. Most importantly, plastics are light, cheap and easy to purchase.

Furthermore, the product should send haptic feedback and a produce a light, which will notify the user. This is established by installing a vibration motor and a LED into the bracelet. This vibration motor will vibrate when certain parameters are met. This is the same case for the LED. So, by means of vibration the user will be notified with haptic feedback and a LED will emit light in order to give the user feedback by virtue of a light.

Moreover, in order to communicate autonomously between the bracelet and the shoe some type of communication device is necessary. This will in fact be a radio module, which can send and receive data. This data will hold the measurements done by the sensors on the shoe. These measurements are the distance between the shoe and an object. This data will be sent and processed by a micro controller, that will control the whole product, therefore, making it work autonomously for the user. The only interactive operation the user should do is putting the device on. Summarizing, the product will be autonomous, by the sensing and transferring data between micro controllers, which will handle the received data and make sure that the user is alerted.

Nevertheless, even if the product works perfectly, it can always endure millage by the form of bumping into objects and just simple usages. During the use of the product, a lot of mistakes could be made on the side of the user, like dropping a glass of water on the floor or simply letting something on or the device itself drop from great height. Due to the inhouse use, it should not have to endure full weather scenarios. However, making the product splash proof could enlarge the lifespan of the product. Because there is always a risk of splashing water onto the product. Furthermore, a protective case for splashes will also have another benefit. It will also protect for bumping it into something or dropping the product.

To specify under what circumstances the device works perfectly, the technical specification will be given. These specifications consist of the range of different sensors, the range of the radio module, the battery life of the bracelet and the shoe sensor and many more parameters induced by the software.

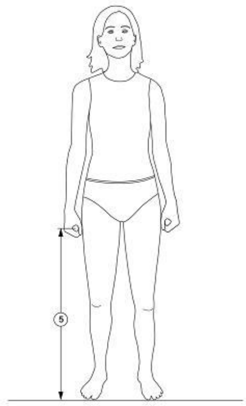


Figure 7, Fist height. (Motmans, 2005)

First, the range of both the radio module and the ultrasonic sensor will be specified. For these ranges the user group must be specified. In our case it is elderly. A Belgian researcher (Motmans, 2005) did research into the height of people in the age group between 65 and 80 years old, for standing, siting, hands, feet and weight. From this study it can be concluded that 95% of the people in this age group will have a smaller fist height than 822 mm (see fig. 7). So, if the radio module has a maximum range of 822 mm 95% of the people will be satisfied by the working of our product. In fact, if the range of the radio module will be 1m it will account for 99% of the people and make sure that if any interference happens the product will still work. This interference could be created by walking, interfering objects, such as plants or your own hand and other nearby radio sources. So, setting the minimum range of the radio module to 1 m will secure that the radio modules could communicate with one another, no matter the case. The ultrasonic sensor does not depend on the dimensions of the user; however, it does depend on their reaction time and the processing speed of the product. If someone has a slow reaction time, they should be notified earlier, than if they had a reasonably quick reaction. In addition, if the product is slow with processing the measured data, it could increase the time between measuring a too small distance and notifying the user. So, the processing of the code should be done withing a couple of milliseconds, in order to not influence the reaction time of the user. A quite fast walking speed is around 1.5 m/s, this will certainly not be achieved indoors by elderly. So, if the ultrasonic sensor could measure distances at least up to 1.5 meters. The user could have a reaction time of 1 second. Which should be sufficient in all cases. Concluding, the radio module should at least have a range of 1 meter to make sure that the radio modules can communicate, without interference for all people. The same holds for the ultrasonic sensor. If it can measure distances of at least 1.5 meters should be sufficient for all types of users.

Regarding the battery life, it should not be depleted in a short time span. To make sure that the user will not get bothered by continuously replacing the batteries, the batteries should at least last a full day on maximum energy depletion. If the batteries can sustain a full day on maximum load, which is when the electronics are continuously operating, then the batteries life can be stretched even more by making sure that the product is not working always on maximum power. This can be achieved by changing certain settings in the software.

To conclude, the technical specifications should be defined, because it is the red wire to making sure that the product will hold to all expectations. Therefore, our product should at least have an operating range of 1 meter to make sure that there will always be a stable connection between the shoe and the bracelet. Furthermore, the sensor on the shoe should at least be able to detect distances larger than 1.5 meters. This is to secure that all people have enough time to react.

Detailing

In this section the functions of the preliminary design are translated into components. These components can either be manufactured or purchased. The components should cover the complete design and account all functions the product should have. Detailing should be done to cover all aspects of the design and make sure all parts can be connected and work together. This includes how everything is connected, how the construction will be done and how components will fit together. If this is not done right, the product might not fit or even worse, fail to work. So, to make sure this will not happen, carefully considering which parts should be which and determining different construction methods, should ensure that the product will turn out in the intended way. Firstly, all functions of the design are translated to the corresponding part(s) and construction method(s). At the end, three most important and interesting parts will get a more elaborated view, to fully highlight the corresponding component and explain it in full detail.

In short, it follows from the functional design and solutions, that the product should alert users, communicate between the shoe and the bracelet, detect obstacles, fit on every shoe, be powered on the shoe/bracelet, be splash and shock proof and at last it should work interactively with a user.

Firstly, all function with respect to electronics are given. These functions are alert users, communicate between shoe and bracelet, detect obstacles, power source on shoe/bracelet and work by interaction with user. All the electronics need to be wired together and need to get controlled, such that it will operate in our likings. To do this, in between different electronical parts a microcontroller should be present. A microcontroller is a programmable, electrical device with multiple in and output pins to control electrical components. Both the shoe and the bracelet need a microcontroller, because both will need to interact with electronics. The microcontroller chosen for the bracelet is the Arduino RF-Nano and for the shoe the Arduino LilyPad Mainboard.

Now that the microcontrollers are chosen, a device to communicate between the two microcontrollers is needed. The solution for this is a radio module. Two radio modules can communicate wirelessly with one another by the means of radio waves. The radio module of choice is the NRF24L01, this chip is already preinstalled on the Arduino RF-Nano, however, it still needs to be connected to the Arduino LilyPad. All Arduino boards can communicate via serial peripheral interface (SPI), this is indeed the means we need to communicate with the radio module. Once the radio module is attached to the Arduino LilyPad, the two microcontrollers can communicate with one another.

The shoe still needs some type of sensor to accomplish the function of it being able to detect obstacles. This can be done by some type of sensor. In fact, an ultrasonics sensor is perfect for this job. The ultrasonic sensor we choose is the RCW-0001, because it is quite small and has reasonable operating distances. The sensor can be connected directly to the Arduino Lilypad. This will make sure that the measured data can be transmitted towards the Arduino RF-Nano.

The Bracelet still needs to fulfill the function that it should alert the user. To alert the user a LED and a vibration motor was chosen. The color of the LED is red and since it is connected to a microcontroller which has a digital output voltage of 5V. Then, a 100Ω resistor is needed. The vibration motor can be connected directly to the bracelet without having problems.

The last electronical functions of the design are that the power source should be on the shoe/bracelet and that the user can interact with the product. In order to execute our product, without being plugged into an outlet or a PC, a type of power supply is needed to give electrical energy to the components when it is not powered by a cable. Having two parts, the bracelet and the part for the shoe, complicates matters. The battery requirements heavily depend on the electronics used. The electronics in the shoe do not need a lot of power so a smaller less capable battery could be used. Furthermore, this battery does not have to withstand high power usage, due to the high efficiency of the Arduino LilyPad. Therefore, the chosen battery is a 3V lithium button cell CR2032 battery. This battery can directly power the Arduino LilyPad. The Arduino RF-Nano requires a lot more power, moreover, the vibration motor also requires a lot of power, which a simple 3V battery could not provide. Therefore, a 9V lithium battery is used for the bracelet. Both batteries could be connected to the Arduino boards with a switch in between, the switch makes sure that the user could turn the product on and off at any time.

There are still some functions not accounted for, because these cannot be solved with electronics. These functions are to fit on all shoes and to be splash/shock proof. The function of the product being splash/shock proof can be solved by the same solution.

Simple splashes can be easily avoided by encasing all the water sensitive parts. This case then directly works as a shock proofing device. In order to get a perfect fitting case with the above-mentioned electronics, a case should be manufactured, such that it will hold to the predefined functions. A simple 3D-printed, plastic case will be sufficient for splash and shock proving the device.

Furthermore, in order to let it fit on all shoes an elastic band is used to account for different shoe sizes. The stretchiness of the elastic band secures that this function is achieved. However, people also have different wrist sizes. To account for this fact, the wrist band will be made of a watchband type material with a buckle, so that users can change the length of the bracelet.

The 3D-printed cases will also make sure that every component will fit neatly together and hold everything together.

Since all functions are now transcribed to parts of the design a more elaborated view on three of the parts will be given below.

One of the most important aspects of the design are the microcontrollers. The microcontroller is the brain of the operation; therefore, it is essential to choose the right microcontroller, which can handle the type of operation perfectly. One of the biggest manufacturers of microcontrollers is Arduino. The boards from Arduino have a lot of diversity and come with open-source software. Furthermore, their boards are often one of the cheapest and do not require a lot of in-depth knowledge.

To determine which board is the most sufficient for our project a look at the technical specifications and the MoSCoW-list will be useful. From these lists the product should be as small as possible. This will immediately decrease the number of possible microcontrollers, however, both the microcontroller in the shoe and in the bracelet need to operate a certain amount of electronic hardware. If a too small board is chosen, it will not have enough pins to connect to all the electronics. This will result in a failure of the product. Therefore, a good consideration between minimizing the size of the board and the utility of the board must be taken.

The board for the bracelet was a relatively easy choice. The chosen board is the Arduino RF-Nano, this board is essentially the Arduino Nano, which is a compact board with more than enough pins to connect all electrical components, with a build in radio module. The build in radio module is the main reason for choosing this board, because it will give multiple benefits. These benefits are a reduction in costs, this comes from the fact that the Arduino RF-Nano is cheaper than the Arduino Nano. Furthermore, an additional radio module must be purchased if an Arduino Nano is chosen. Moreover, the built-in radio module also decreases the size of the product, because an external radio module will be slightly bigger and must be somehow connected to the board, which can be a tricky task. The built-in radio module also decreases the number of pins that will be used, however, this was not a problem, because the number of pins on the Arduino Nano was more than sufficient.

The shoe also needs a microcontroller. The board we used is the Arduino LilyPad Mainboard. This board is essentially a better and more advanced version of the normal, smaller Arduino LilyPad, because it has more available pins and has a quicker processor. The quicker processor matches the clock speed of the Arduino RF-Nano. This will be useful for matching the software on both microcontrollers. The reason to choose the Arduino LilyPad was the fact that it has a flatter design. This flat design will secure the fact that it should not impede walking. Furthermore, a flat design will look more aesthetically pleasing. Another important aspect to choose the Arduino LilyPad was costs. In order to create a shoe sensor for both shoes and fit in the budget of €70. All the components must be purchased and manufactured twice, so reducing the cost of the boards even more will help stay it underbudget.

To conclude, the Arduino RF-Nano will be more space efficient than the Arduino Nano. Furthermore, both the Arduino RF-Nano and the Arduino LilyPad Mainboard will ensure that the cost stay low. The Arduino LilyPad will also make sure that the size for the shoe sensors stays flat, which eventually looks more pleasing to the eye of the user.

The solution for the batteries seemed quite straightforward; however, it surely was not. Due to the devices not being powered by an outlet, but by batteries. It is quite important that these batteries have significant capacity, such that, they will not have to be swapped every hour. The capacity of a 3V button cell battery is relatively low. Luckily, the Arduino LilyPad has a good efficiency, so this 3V battery can still easily last for more than a day while the Arduino LilyPad is performing at maximal power.

Nevertheless, the Arduino RF-Nano requires a lot more power, not only is the minimal, necessary input voltage two times higher. It also needs a lot more power to operate. In addition, the vibration motor is attached to the Arduino RF-Nano. This also requires a strong voltage source. The 9V battery solution then seems logical, however, a 9V battery quite large, so in order to fit it would make it difficult or unpleasant for the user.

Another solution could be the usage of multiple 3V batteries to increase the capacity, therefore, the battery lifespan. Then boosting the voltage of the source to 5V to power the Arduino RF-Nano, however, this 5V needs to be perfectly stable in order to power the Arduino RF-Nano and if this is the case this source can only power the microcontroller itself, so connecting the vibration motor will not be of any use, due to it being impossible to power both the vibration motor and the Arduino RF-Nano at the same time. Another solution could be boosting the voltage source even more, to a voltage of 7-12V. This would overcome the problem of not being able to power the Arduino RF-Nano and the vibration motor at the same time, but now the power usage of the device will increase significant. Now even two batteries will not be enough to sustain a reasonable battery lifespan. So, it will not be possible to have a reasonable battery lifespan, without having a ridiculous number of batteries.

After all, the 9V battery was the best solution in the first place. The solution is simple and does not require other components to work. Furthermore, it has the best ratio between battery lifespan and size.

As for the programming, the Arduino language was used, within the Arduino IDE. Two files have been created: one for the transmitter and one for the receiver. The libraries we used are *SPI.h* - Serial Peripheral Interface (SPI) is a synchronous serial data protocol used by microcontrollers for communicating with one or more peripheral devices quickly over short distances. It can also be used for communication between two microcontrollers., *NewPing.h* which helps send a ping, returns the echo time in microseconds or 0 (zero) if no ping echo within set distance limit and *RF24.h* - core library for nRF24L01(+) communication.

In short, the code asks the ultrasonic sensor to send a ping and return the echo time(duration) from which the distance is calculated using the speed of sound constant. The result is transmitted to the RF-Nano's built-in radio, which then sends the value to the board for it to be compared with the 15 cm value and decide whether the user should be alerted or not. If so, then the LED is flashed and at the same time the vibration motor toggles between on and off (see appendix A & B).

Realization

Electronics

Regarding the electronics, they first must be tested separately, to make sure that all the components work and fit together. So, the steps that need to be taken before the final assembly of the electrical circuits are making a schematic of the circuit, then actually building the circuit on a breadboard and finally soldering everything together. The schematic ensures that the building of the circuit is easy and is repeatable. This is especially useful for programming the software and soldering the hardware. After a clear schematic is created, the testing on the breadboard can begin. This testing is useful for making sure that all the components work together and to check that the schematic works like intended. When this is finished all the components can be soldered together.

Because our product is split in two separate modules, two different circuits must be built. The circuit for the bracelet contains the Arduino Rf-Nano, vibration motor, LED, 9V battery, switch and a resistor. The corresponding schematics can be seen in figures below. In figure 'Schematic Shoe' the schematic for the shoe can be seen. In this schematic there is an Arduino LilyPad, an ultrasonic sensor, a 3V battery, a radio module and a switch.

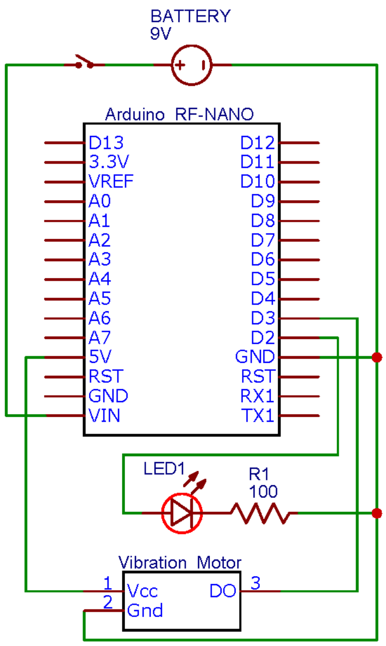


Figure 8: Schematic bracelet

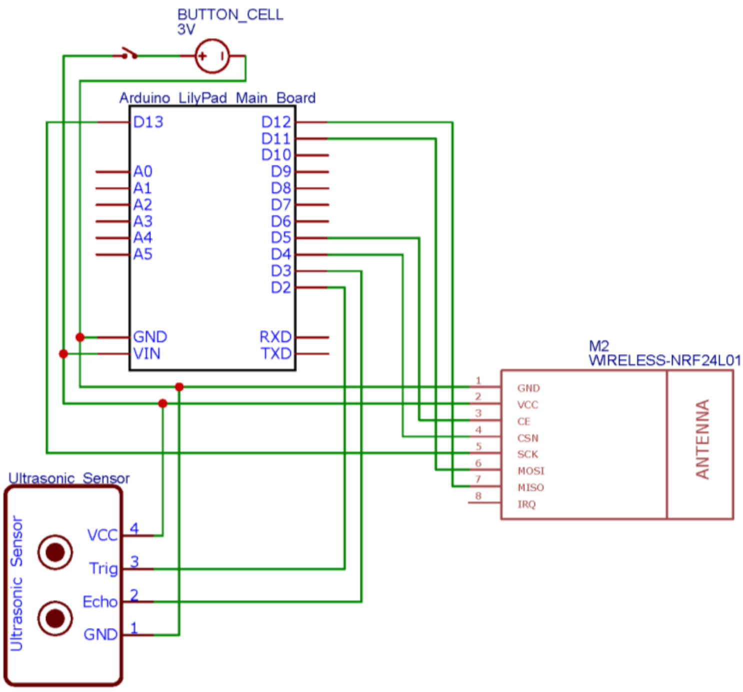


Figure 9: Schematic shoe

With these schematics finished, testing of individual parts could begin. To test the individual parts one of the circuits is built on a breadboard and connected to a PC. All individual components could be tested by uploading simple code to the Arduino. The circuit corresponding to the schematic in figure 'Schematic bracelet' is built in the figure below. In this figure individual components for the bracelet could be tested. From these tests it was clear that all the individual components worked. However, all the separate components still had to fit and work together.

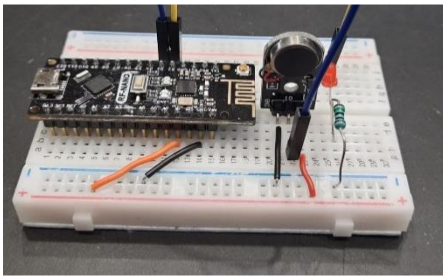


Figure 10: RF-Nano on breadboard with jump wires

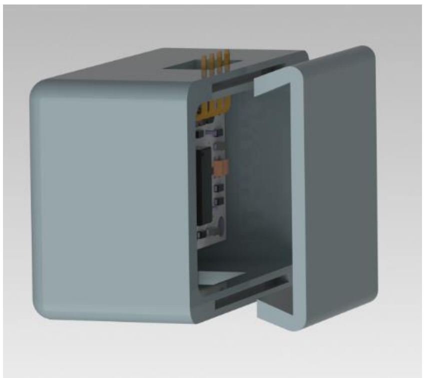
When both circuits will be encased, it is essential to check that all the components will fit neatly together. Furthermore, the ultrasonic sensor must have a clear sight in order to work. From testing it was clear that the proposed encasing did not interfere with the measuring of the ultrasonic sensor.

Since all parts were tested and indeed fit together. It was ready to be soldered. Due to the schematics, it was easy to replicate the circuits from testing into the soldered circuit.

CAD Modelling

To start the process of making CAD models measurements of the various components were found. Along with this, models of these electrical components were found online to assist in modelling and their dimensions were verified with the real-life counterparts. Once all the components were found and imported into NX12 modelling could begin. Many iterations of the design were made based testing done on early printed parts.

Each design was made with a desire to minimize the size of the part and allow efficient packing of the electrical components. The ultrasonic sensor cage was designed to protect and hold the ultrasonic sensor that would be placed on the front of the shoe. It only exposes the speakers of the sensor and covers the rest to protect it from damage. The LilyPad case is made for holding the LilyPad board, RF transmitter and vibration battery. This part is to be placed on the top of the shoe. Finally, the bracelet case was designed to hold the Arduino nano, battery, vibration motor and LED. Unfortunately a better solution for a 9V battery to power this board was not found so the battery would need to be attached to the outside of the bracelet. Some smaller details were changed after the first round of printing like adjusting the size of the back for the ultrasonic sensor case and making a hole for wiring in the LilyPad case.



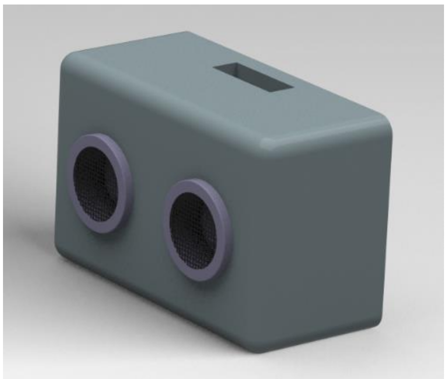


Figure 11: CAD model ultrasonic sensor

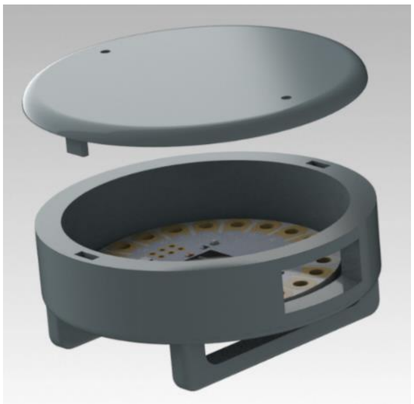


Figure 12: CAD Model LilyPad case

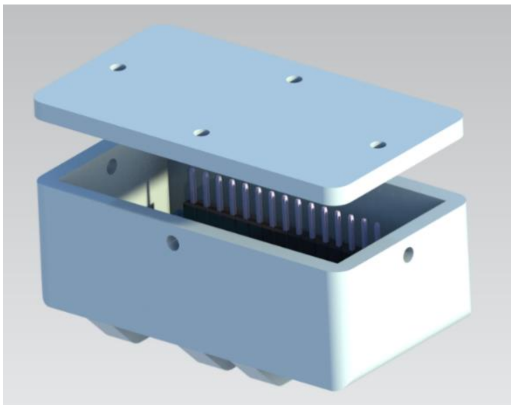


Figure 13: CAD Model bracelet

3D printing

After the modelling, we had to print 3 cases. First, we did a few test prints to check the printer and things we would need to take into consideration. Some components had to be printed separately and glued on later. After our first prints of the boxes, we found out we forgot the wiring in the LilyPad box and that the top of the box was fragile. So, we had to come up with an idea for closing and opening the LilyPad box. We thought of wires in the 4 small holes but for elderly this would be hard to close and open. Then we thought of a big elastic strap around it.

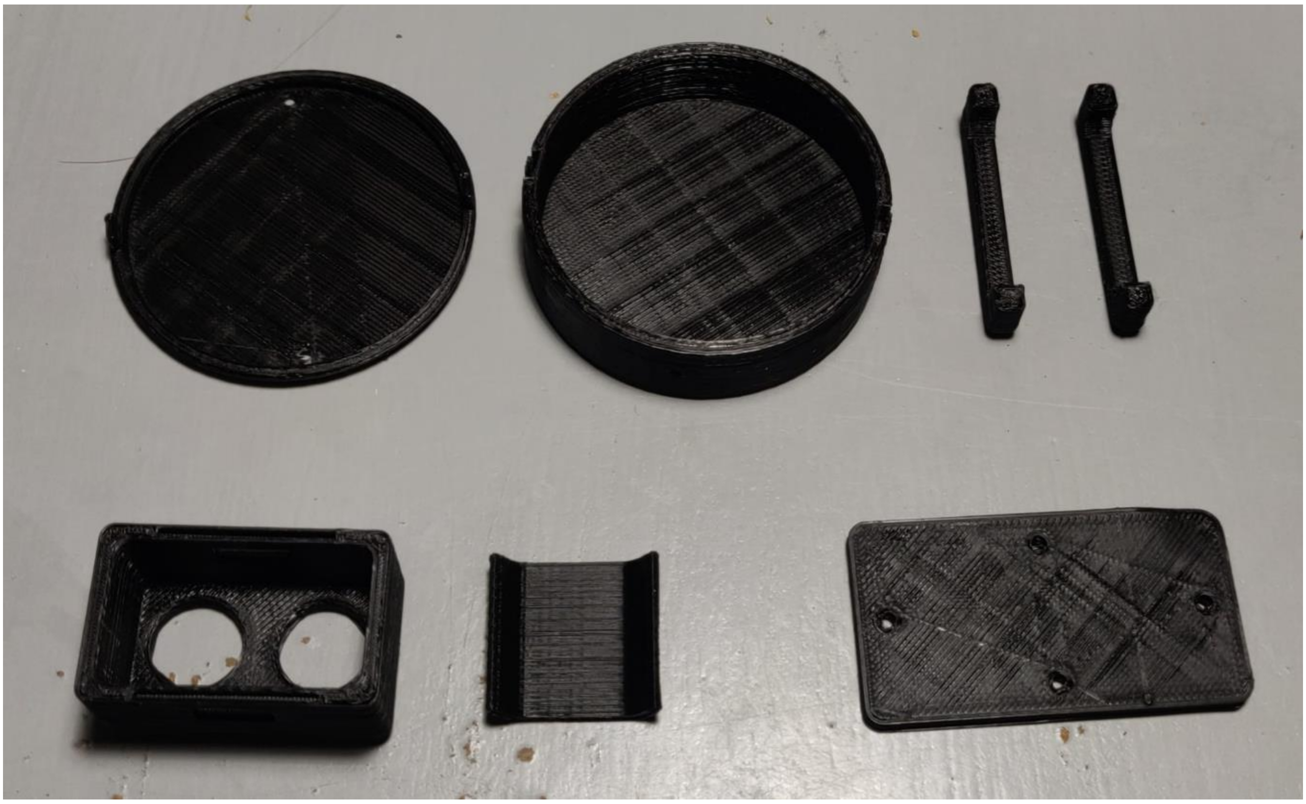


Figure 14: 3D printed parts

Plan of production

To produce the parts needed for the product, a 3D printer was used to manufacture the parts that were not purchasable The electronic components, elastic strap and bracelet were all purchasable. The housing for the electronics was 3D printed using a Zonestar 802Q printer with 1,75mm PLA (Jupiter series) filament. After 3D printing the parts they were fitted with the electronics and the attached to the elastic band and their backs were glued in using super glue. After this the lids were fixed using tape.

The bracelet (see fig. 15) was made with an old belt. The belt was cut and new holes were made to make it adjustable for different wrist sizes. The shoe band was firstly made with a polyester material (see fig 17), which is often used on backpacks. This material was too stiff, so an elastic material was used instead (see fig. 18). The shoe band consists of two band. One that goes around the sole of the shoe and one that goes around the front of the shoe. These two bands were then sewed together on three different points using a sewing machine. The edges of the elastic band were closed using a ultrasonic sewing machine.

Bracelet

Figure 15: Bracelet band

Figure 16: Finished bracelet

Shoe band

Figure 17: Shoe band polyester material

Figure 18: Shoe band elastic material

Figure 19: Finished shoe band

Bill of materials

Below you can see a table of everything we bought for our design.

Table 4: Bill of materials

Part	Type	Brand	Supplier	Qty	Unit	Unit cost	Cost
Alpha Wire	Solid - Ø1.5mm 0.33mm^2	-	TinyTronics	1	Meter	€ 1,00	€ 1,00
Battery	9V	-	-	1	1	€ 2,00	€ 2,00
Battery	9V	Duracell Procell	TinyTronics	1	1	€ 1,75	€ 1,75
Battery	CR2032 3V Lithium	GP	TinyTronics	4	1	€ 0,75	€ 3,00
Battery clip	9V	-	TinyTronics	1	1	€ 0,50	€ 0,50
Battery clip	CR2032-LIR2032	-	TinyTronics	4	1	€ 1,00	€ 4,00
Buckle	-	-	Market	1	1	€ 0,50	€ 0,50
DuPont Jumper wire	Female-Female	-	TinyTronics	1	10	€ 0,50	€ 0,50
DuPont Jumper wire	Male-Female	-	TinyTronics	2	10	€ 0,50	€ 1,00
Elastic band	-	-	Market	2	Meter	€ 3,00	€ 6,00
LED	Red	-	TinyTronics	1	1	€ 0,10	€ 0,10
Microcontroller	LilyPad 5V 16Mhz Mainboard	Arduino	TinyTronics	2	1	€ 6,00	€ 12,00
Microcontroller	RF-Nano V3.0	Arduino	TinyTronics	1	1	€ 8,00	€ 8,00
Mini DC-DC Step-up Boost Converter	5V	-	TinyTronics	1	1	€ 0,45	€ 0,45
Plastic	-	-	-	0,084	Kilograms	€ 19,95	€ 1,68
Radio module	NRF24L01	-	TinyTronics	2	1	€ 2,50	€ 5,00
Resistor	100Ω	-	TinyTronics	1	1	€ 0,05	€ 0,05
Rocker switch	Small	-	TinyTronics	1	1	€ 0,45	€ 0,45
Super glue	-	-	-	1	1	€ 2,99	€ 2,99
Ultrasonic sensor	RCW-0001	-	TinyTronics	2	1	€ 3,25	€ 6,50
USB Serial Port Adapter	FT232RL 3.3V-5V TTL	-	TinyTronics	1	1	€ 6,00	€ 6,00
Vibration DC Motor Module	-	-	TinyTronics	1	1	€ 2,50	€ 2,50
Total							**€ 65,97**

Final Design

Figure 20: Trip Saver

Looking back out our final design concept a few things changed in the final design. We found that we could solely use the elastic band as material around the shoe. This made that we did not have to sew different materials together and that the band is more flexible which makes that the band can be adjusted in the length width and height of the shoe. We also got rid of the rubber/plastic piece on the front and back of the shoe. While making the elastic band we found that the band was enough to keep everything in place and the rubber/plastic pieces wouldn't be necessary. This also makes that it is more comfortable to walk with, because one does not touch the ground with the product.

For the bracelet we didn't change much. First we wanted to make the bracelet from an elastic band, but this would lead to the bracelet being too lose for some people and too tight for others. Finally we used an old belt as a sort of watch band, which is easy to put on for elderly.

Test plan and results

We tried on different strap designs and saw what fit best onto the shoe and felt most comfortable and secure to come up with our final design. We also asked the people we knew from the elderly population to choose between our different design ideas and opt for what they thought was the best regarding ease of use and efficiency. In the end we came to the conclusion that it was best to use an elastic band for the shoe.

After having tested each electronic component separately and confirming it works to its full potential, the next step was mimicking the circuits of then shoe part and the bracelet part on two breadboards. Now, we needed to check whether the radio connection is done properly and if the distance gets measured accurately. We couldn't transmit even a simple string to the RF Nano. We thought this might be caused by the special pins the LilyPad has that might not make contact unless clams are used, which we didn't have at the time and too much time for testing would have been lost if we decide to order some.

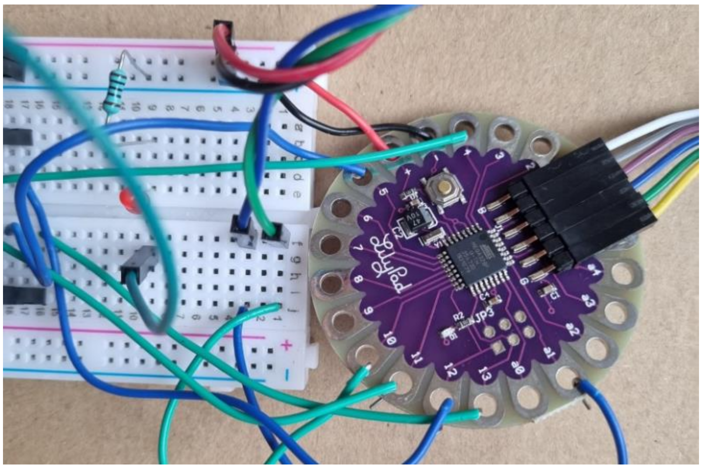


Figure 21: Visualization of Arduino Lilypad's not so reliable pin connections

Another finding was that the ultrasonic sensor was sending measurements only when connected to the RF Nano. This confirmed our suspicions regarding the connectivity issues with the Lilypad.

Another impediment was that within the Arduino IDE, selecting Arduino LilyPad as the board we're working on never lead to successful results and threw errors such as '*avrdude*'. We investigated the issue but couldn't find any solution other than using the configuration for an Arduino Uno. This was also buggy since sometimes the code would simply not get uploaded and needed multiple attempts in order to upload the code to the board successfully and be able to see its behavior.

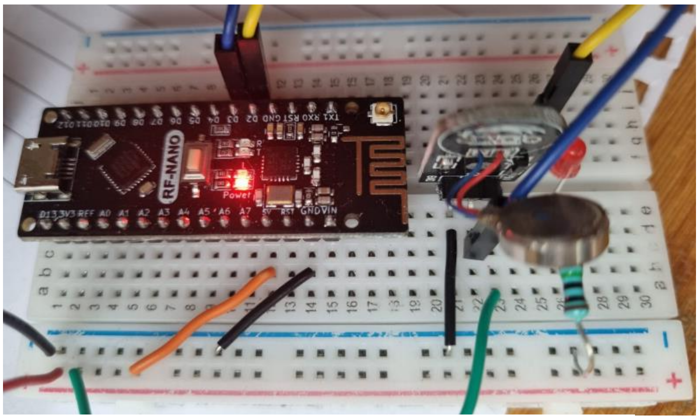


Figure 22: RF-Nano on breadboard

This decision added more steps to our testing process, because we had to test each pin of the Uno configuration to see whether it is the same with the one that the LilyPad has. We did this by connecting an LED with one end on the GND pin and toggling between the numbered pins of the board with the other end. With each toggled pin we changed the number of the pin we are testing in the Arduino-Basics-Blink file, to check if current flows to the selected pin. This part of the testing concluded that the two boards have the same configuration on pins 1 to 13. Thus, one possible impediment of our device not working as we wished has been crossed off.

Next, to solve the issues introduced by the special appearance of the Lilypad pins, we soldered the wires of the radio module and the ultrasonic sensor onto the Lilypad. Testing was still not conclusive, and our proposed shooting day was close, and we decided to solder the other components as well and have our final product ready, which in retrospective wasn't a good idea. We succeeded to measure the distance with the Lilypad, the bracelet vibrated when the distance received was smaller than 15 cm. What still was not behaving as wished were the radio modules. The data that the Lilypad was trying to send to the bracelet just didn't go through and the bracelet constantly received 0 and vibrated. We tried to send strings in various ways, using different libraries, but the RF Nano would still not receive anything. Soldering so early wasn't a good decision because if the components had still been on the breadboard, then some flexibility would have still existed and we could just switch between different pins, cables and see what worked. Having everything soldered together made the code the only step that we could suspect went wrong and try to fix. Or at least the part that we still were able to make changes to.

Design evaluation

The intended design goal of our group was to make a device that alerts the user of obstacles in their walking path, to prevent falls before they happen. With our device we wanted to help elderly become more confident while walking. Resulting in a more active and mobile life, for elderly to live healthier and longer lives. This would in the end would also result in a reduction of medical expenses, since there will be less injuries caused by falls.

To reach our design goal we came up with Trip Saver. We think Trip Saver is a creative, innovative and user-friendly product, but we see there is still room for improvement. Below we will discuss improvements, to make Trip Saver a better product.

The first improvement of our design would be to make the bracelet smaller. Right now, the bracelet is quite voluminous, and it is powered by a 9V battery. This makes the bracelet not comfortable to wear, since it is rather big and heavy. Towards the end of the course we found out that the 9V battery didn't fit in the 3D printed case we made. Because of this the 9V battery needed to place on the outside of the 3D printed case. This made the component that should be put on the bracelet really big and it didn't look aesthetically pleasing. We even got some comments that people found our bracelet looking like a bomb. When people told us, we did understand where they came from with this comment. It was however never our intention to make it look like a bomb. This is something that we should have taken into account earlier on in the process, in order to still be able to change it. For the casing we also found out that the 3D printed case had pretty thick edges and that there was still quiet some room left on the sides of the Nano board, which made the case bigger that necessary. So to improve on this part of our design we should have measured the dimensions of the components all together during the detailing and realization phase. This is something that we should have done together, so sitting all together with the electronical components and the CAD modeling, instead of apart. In this way we would have probably come up with a better fitting bracelet case.

Another improvement of our design would be to make it more durable. We already made the device more durable, by casing the electric components. In this way the components were protected against water and bumping into objects. However our design still has some wires over the front of the shoe, which makes the it less durable and sturdy. To improve this we could put the wires in a plastic hose, which is very flexible and helps against water. We could also put the wires in a hose made from fabric or made from the elastic band we also used for the shoe band itself. This material is however not completely water proof, but it would probably look more aesthetically pleasing. This implementation would be done during the realization part and we think this would make our design even more durable.

The lid of the Lilypad case is another thing that could be improved in our design. In our CAD modeling we designed the case and lid in such a way that it could be clicked together. However this didn't turn out that well when the case was printed. This has probably to do with the accuracy of the 3D printer we used. Right now the lid needs to be taped to stay in place, so we should implement some changes to the design to make it click and not come apart unless wanted. A more accurate 3D printer would be a good alternative, in order to try if our initial CAD model, with the clicking system, would actually work. If it turns out that this clicking system doesn't work using a more accurate 3D printer, we would need to come up with an alternative. One of the alternatives would be an elastic band that would secure the lid on the box. This is an alternative we already tried during the course and turned out to be working pretty well. The only downside is that it doesn't look as aesthetically pleasing as the clicking system. These changes should be done in the detailing and realization phases of our design process.

A last improvement of our design would be to find a more reliable way to connect the bracelet to the shoe. In our design we currently use a radio module to connect the bracelet to the shoe. During the programming we found it pretty difficult to connect the RF-Nano to the two radio modules in the shoes. Because of this we weren't able to have a working prototype during the final presentation, which we thought was really disappointing. During the course we also looked into Bluetooth, but this turned out to be too expensive. This implementation should be done early on in the process, since the rest of the project really depends on the choice you make for the connection. So this implementation should be done in the technical specification phase.

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Appendices

Appendix A: Code for transmitter

code-for-transmitter.ino file

```
// Include NewPing Library

#include "NewPing.h"
#include <SPI.h>
#include <RF24.h>

// Hook up RCW-0001 with Trig to Arduino Pin 10, Echo to Arduino pin 13
// Maximum Distance is 400 cm

#define TRIGGER_PIN  2
#define ECHO_PIN     3
#define MAX_DISTANCE 400

NewPing sonar(TRIGGER_PIN, ECHO_PIN, MAX_DISTANCE);

int iterations = 5;

RF24 radio(5, 4); // CE, CSN
const byte address[6] = "00001";

void setup() {
  // Setup Serial Monitor
  Serial.begin(9600);

  radio.begin();
  radio.openWritingPipe(address);
  radio.setPALevel(RF24_PA_MIN);
  radio.stopListening();
}

void loop() {
  float duration, distance;

  duration = sonar.ping_median(iterations);
  Serial.print("Duration: ");
  Serial.println(duration);

  // Determine distance from duration
  // Use 343 metres per second as speed of sound
  distance = (duration / 2) * 0.0343;

  radio.write(&distance, sizeof(distance));

  // Print values to Serial Monitor
  Serial.print("Distance: ");
  Serial.println(distance);
  Serial.println();

  delay(1000);
}
```

Appendix B: Code for receiver

code-for-receiver.ino file

```
#include <SPI.h>
#include <RF24.h>

int motorPin = 3;
int ledPin = 2;

RF24 radio(9, 10); // CE, CSN
const byte address[6] = "00001";

void setup() {
  Serial.begin(9600);  // Use this for debugging

  pinMode(motorPin, OUTPUT);
  pinMode(ledPin, OUTPUT);
  digitalWrite(ledPin,LOW);
  digitalWrite(motorPin, LOW);

  radio.begin();
  radio.openReadingPipe(0, address);
  radio.setPALevel(RF24_PA_LOW);
  radio.startListening();
}

void loop() {
  float distance;

  if (radio.available()) {

    radio.read(&distance, sizeof(distance));

    // Print values to Serial Monitor
    Serial.print("Distance: ");
    Serial.println(distance);

    // Flash LED and toggle vibration motor between on and off when distance
< 15 cm
    if (distance <= 15) {
      digitalWrite(ledPin, HIGH);
      digitalWrite(motorPin, HIGH);
      delay(1000);
      digitalWrite(ledPin, LOW);
      digitalWrite(motorPin, LOW);
      delay(500);
    }
  }
}
```

Appendix C: ERB form

Ethical Review Form Education

This Ethical Review Form should be completed for every research study that involves human participants or personally identifiable data. The form should be submitted and approved by your supervisor before potential participants are approached to take part in the research study.

Part 1: General Study Information		
1	Student name and email	-
2	Supervisor name and email	-
3	Degree Program	Multi-disciplinary
4	Bachelor/master	Bachelor
5	Bachelor/master end project?	No
6	Course name and code	Engineering Design 4wbb0
7	Project title	Trip Saver
8	Research location	At the users house or university
9	Research period (start/end date)	8 October – 1 November
10	[If Applicable] Proposal already approved by (external) Ethical Review Board: Add name, date of approval, and contact details of the ERB	Is your study part of a larger study that has been ethically reviewed before? Then describe the details of that ERB approval.
11	Research question	Try out the prototype
12	Description of the research method	The participant is asked to test our device. This would mean wear the bracelet and the shoe sensor. With this we want to research how people interact with the device and help us determine if the distance and alert is good.
13	Description of the research population, in- and exclusion criteria	Our research population consists of different age groups

14	Number of participants	5
15	Explain why the research is socially important.	Our device can help elderly become more confident while walking, which would lead to more active lifestyle.
16	Describe the way participants will be recruited	Email, what's app or mouth to mouth
17	Provide a brief statement of the risks you expect for the participants or others involved in the research and explain. Take into consideration any personal data you may gather and privacy issues.	Are there any risks involved for the participants or others involved in the study? Think about what participating in the study will entail for them, what type of data your will collect and how you will make sure these data will be kept safe —> the users have no risks and the data will be kept safe during the research period. After the research period the data will be destroyed.

		Part 2: Checklist for Minimal Risk	
		Yes	**No**
1	Does the study have a medical scientific research question or claim (see definition below) *Medical/scientific research is research which is carried out with the aim of finding answers to a question in the field of illness and health (etiology, pathogenesis, signs/symptoms, diagnosis, prevention, outcome or treatment of illness), by systematically collecting and analysing data. The research is carried out with the intention of contributing to medical knowledge which can also be applied to populations outside of the direct research population.'*	☐	☒
		If yes or maybe: Your supervisor should submit the study to the ERB. You cannot get automatic ethical approval	If no: Continue with question 2
2	Does the study involve human material (such as surgery waste material derived from non-commercial organizations such as hospitals)?	☐	☒
		If yes or maybe: This is only allowed if your supervisor has consulted with the medical coordinator. Continue with question 3	If no: Continue with question 3

3	Will the participants give their explicit consent – on a voluntary basis – either digitally or on paper? Or have they given consent in the past for the purpose of education or for re-use in line with the current research question?	☒	☐
		If yes: Continue with question 4	If no: Your supervisor should submit the study to the ERB. You cannot get automatic ethical approval
4	Will the study involve discussion or collection of personal data? (e.g. name, address, phone number, email address, IP address, BSN number, location data) or will the study collect and store videos, pictures, or other identifiable data of human subjects?	☒	☐
		If yes: The handling, storing and de-identification of the personal data should be discussed with your supervisor. Continue with question 5 if you met all requirements for handling personal data (see …)	If no: Continue with question 5

		Yes	No
5	Does the study involve participants who are particularly vulnerable or unable to give informed consent? (e.g. children, people with learning difficulties, patients, people receiving counselling, people living in care or nursing homes, people recruited through self-help groups)?	☐	☒
		If yes: Your supervisor should submit the study to the ERB. You cannot get automatic ethical approval	If no: Continue with question 6
6	May the research procedure cause harm or discomfort to the participant in any way? (e.g. causing pain or more than mild discomfort, stress, or anxiety)	☐	☒
		If yes: Your supervisor should submit the study to the ERB. You cannot get automatic ethical approval	If no: Continue with question 7
7		☐	☒

	Will the participants receive any compensation for their participation? Such as a coupon or a chance to win a prize?	If yes: Your supervisor should submit the study to the ERB. You cannot get automatic ethical approval	If no: Continue with question 8 or 10, depending on the type of study (see red text below)
The following questions 8-9 are for *observational* research (e.g. (semi-)structured interviews; focus groups; (participatory) observations). If your research is *experimental*, then skip questions 8-9 and continue with question 10			
8	Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g. covert observation of people)?	☐	☒
		If yes: This is only allowed when observing behavior in public space. If so, continue with question 9. If you observe people in non-public space without their consent, your supervisor should submit the study to the ERB. You cannot get automatic ethical approval	If no: Continue with question 9
9	Will participants be asked to discuss or report sexual experiences, religion, alcohol or drug use, or suicidal thoughts, or other topics that are highly personal or intimate?	☐	☒
		If yes: Your supervisor should submit the study to the ERB. You cannot get automatic ethical approval	If no: Continue with part 3

The following questions 10-13 are for *experimental* research (e.g. measurements on yourself or another person; testing a prototype/device; influencing behavior through manipulation (e.g. light or temperature). If your research is *observational*, then skip questions 10-13 and continue with part 3		
	Yes	**No**

10	Is the study invasive (i.e. it affects the body such as puncturing the skin; taking blood or other body material (such as DNA) from the participant)?	☐ If yes: Your supervisor should submit the study to the ERB. You cannot get automatic ethical approval	☒ If no: Continue with question 11
11	Does the device have a medical purpose sucs as diagnosis, prevention, monitoring, prediction, prognosis, treatment or alleviation of disease or injury?	☐ If yes or maybe: Your supervisor should submit the study to the ERB. You cannot get automatic ethical approval	☒ If no: Continue with question 12
12	Will the experiment involve the use of physical devices that are ‘CE’ certified for unintended use (meaning you will use existing CE certified devices for other things than they were originally intended for?	☐ If yes: This is only allowed if they are completely harmless. They should have a harmless voltage of <5V and hazardous waste (fumes/gas/substances) should not be released. You should discuss with your supervisor whether you need to have the device tested for safety	☒ If no: Continue with question 13
13	Will the experiment involve the use of physical devices that are not ‘CE’ certified?	☐ If yes: This is only allowed if they are completely harmless. They should have a harmless voltage of <5V and hazardous waste (fumes/gas/substances) should not be released. You should discuss with your supervisor	☒ If no: Continue with part 3

		whether you need to have the device tested for safety	