A view for blind people

IPD14 - Final Report

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A view for blind people

Preface

That which follows contains all design choices, information, documentation and recommendations for the IPD14 project '*A view for blind people*', which is a 3rd year project from the Fontys University of Applied science in collaboration with Peters MDT. This is an interdisciplinary project formed by three electrical engineering students, two mechanical engineering students and one applied physics student.

Particular acknowledgments go to Peter Peters from Peters MDT, for providing the assignment and funding, and Gerard van Bokhoven from the Fontys University of Applied science, for his support during the assignment.

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Abstract

As a part of our Bachelor degree at the Fontys University of Applied Science we started an IPD-project (Integrated Product Development) on the 11th of February 2009. The project team consists of 3 electrical engineers, 2 mechanical engineers and 1 applied science engineer. The team is mentored by Mr. Gerard van Bokhoven from the Fontys University. The company which provides the project assignment is Peters M.D.T.

The provided assignment is to develop an aid which can be used by visually challenged people. The aid helps them to move around by giving off a vibrating signal when an obstacle is in their way. For ease of use the device is integrated in the shoe of the user.

The assignment can be divided in 2 major parts:

- The development of the electronics, which is done by our electrical engineers.
- The development of a housing and mounting system for the electronics in/on the shoe, which is developed by our mechanical engineers.

The development of the electronics resulted in following block diagram:

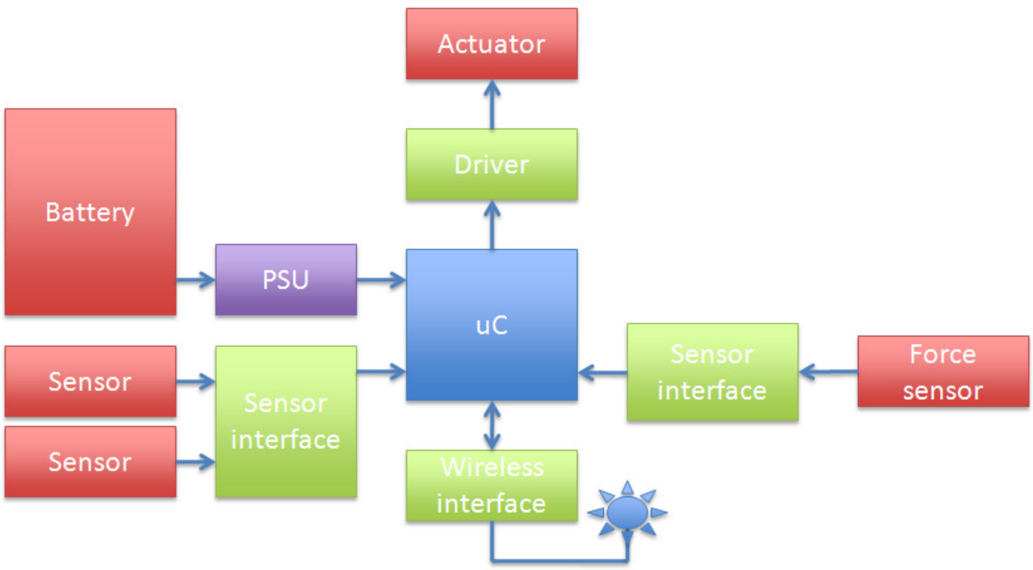

Figure 1, Block diagram electronics

The only problem which occurred during the development of the electronics was an effect called ‘transducer ringing’. This forced us to use a separate transmitter and receiver instead of a transducer.

The development of the mechanical system was without incident. The only problem was that occurred was to need to modify the housing in a late stage, because of the use of a separate transmitter and receiver.

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1. Introduction

1.1 Sponsor

Peters MDT is a freelance company founded by Peter Peters. This company is aimed at inventing aids for people who are sighted or have a hearing impairment. The main purpose of these aids is to simplify there daily life's.

His preference to collaborate with the Fontys University of Applied Science is because he successfully developed a product with students from a previous IPD project, they made drums for partially hearing people.

He has also developed the 'tast-grijp-hulp' for blind people. This device is attached the clients hand and gives them the ability to detect an object when approached by their hand. This way, the client knows then to grab the object. The next idea from Peters MDT is to develop something for the mobility of blind people, based on the technology from the 'tast-grijp-hulp'. This is how the idea of our project 'A view for blind people' was born.

1.2 Objectives

Mr. Peters, from Peters MDT, indentified several objectives for our project. These objectives are (in order of importance):

1. Conduct experiments to determine the best sensors for object detection. Sensors should be compared on properties like: accuracy, price, weight, size, power requirements.
2. Build a prototype of the shoe as described in the patent. The shoe should be thoroughly tested and recommendations should be made for future improvements of the patent.
3. Conduct experiments to determine the best sensors for depth measurements. The sensors should be able to operate reliably while the user is moving.
4. Build a prototype of the belt to accompany the shoes. This belt should be build in accordance with the patent. The belt should also be thoroughly tested and recommendations should be made for improvement.
5. Research the possibility of adding a GPS module to the belt. This module should give the user the option to be guided along a predefined route. The research should focus on the feasibility of using a GPS module and the required accuracy of the positioning system.

More specifications on the objectives are listed in the appendix M and the SSD. Mr. Peters made it clear that we should primarily focus on objective 1 and 2, as realistically, this will probably be all there is time for.

2. Feasibility study

A feasibility study was conducted to determine the viability of the project. From this study there was concluded that the project is viable. This conclusion is mainly based on following four arguments:

- The previous correspondence of Mr. Peters with several company's and foundations specializing in developing aids for the visually handicapped suggest that there is a large market for this device.
- Due to the patent, there are (virtually) no competitors. There is only one competing company which is developing a similar device, called the I-cane. But they use another implementation, as they mount the sensors on the white cane instead of the shoes and belt.
- It should be technically feasible to measure depth and distance using currently available sensors.
- Further research in the above two arguments also showed that Mr. Peters idea's will have a quicker time to market then its competitor. This will ensure a high return on investment (ROI), as blind institutions are like to buy the first (properly) working solution.

3. Preliminary study

An extensive preliminary study was performed after the feasibility study. The following paragraphs discuss the results of this study for all, at that time, identified sub-problems. More information on these studies is located in the appendices.

3.1 Sensor mount

There were two basic ideas for the attachment of the sensors to the shoe:

- Integrate the sensors directly in the sole of the shoe.
- Develop a housing containing either the sensors or both the sensors and electronics, which is mounted on top of the shoe.

At first the first idea seems to be the most logical solution. But this option requires that the electronics must be integrated in the midsole. This requires a really thick midsole, which must be milled out to form a compartment for the electronics. This is not feasible considering that most shoes only have a midsole of a couple of millimeters. Only working or hiking boots will have a midsole of the required thickness.

Furthermore, the second idea has the advantage of the possibility to adjust the scope of the sensors after they are mounted on the shoe. By using the nuts beneath the metal plate (see figure 1), the pitch of the housing can be changed. The yaw can be adjusted by using the bolt in the middle. The sketch of the second idea can be seen in figure 1.

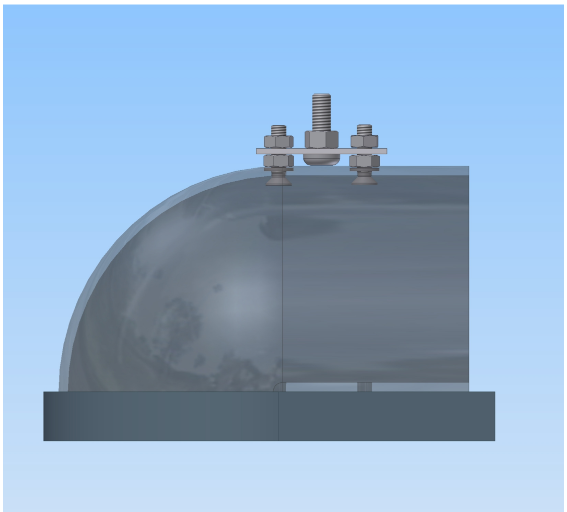

Figure 1, Housing mount

3.2 Materials housing

To comply with the set requirements, weight, durability and discomfort, the housing material should comply with the next requirements:

- Light weight; as the housing is placed on top of the shoe, it should not be too heavy, which restricts the user in its movement.
- Durable, strong (hardness and stiffness); Using the device will expose it the reparative impact; the material must be able to withstand these.
- Easily machined; to create the housing in the workplace of the Department of Engineering at Fontys Eindhoven, the material has to be made through milling and drilling.
- Cheap; the project is bound by a strict budget, the material(s) may not be too expensive.

Looking at these requirements, the decision was made that the material for the housing will be polyvinyl chloride (PVC). This plastic has a smaller density compared to, for example, aluminum or steel (density PVC: 1.35 g/cc -- aluminum: 2.70 g/cc), but is still strong en durable enough for our purposes. Besides this, PVC is easy to machine and inexpensive (€4.-/kilo).

3.3 Force sensor

The force sensor is used to determine whether the user moves. This is necessary as it is impossible to acquire reliable measurements while the shoe is moving. There is chosen to use a Force Sensing Resistors (FSR), which is a variable resistor which depends on the applied force. An advantage of the FSR above other sensors is its thinness, which is only 1mm. Because of this the user receives minimum discomfort from the sensor, while wearing the shoe.

3.4 Object detection

After studying different methods for object detection, like laser, radar, IR sensors ultrasonic sensors and 3d stereo vision. There was concluded that ultrasonic sensors are the best solution, because they are immune for many changes in their environment (colour, sun, temperature). And they are small, cheap, and require little power to operate.

The placement of the sensors on the shoe is based on the patent form Mr. Peters. One sensor is placed at the front and one sensor at the side. The one at the side will detect walls or curbs, so the blind person can keep the same distance to these obstacles and walk along them. In the original drawings, the sensors at the side were placed perpendicular on the walking direction. Instead of this, it is better to line up the sensors slightly off normal, because ultrasonic sound always reflects specula (see figure 2).

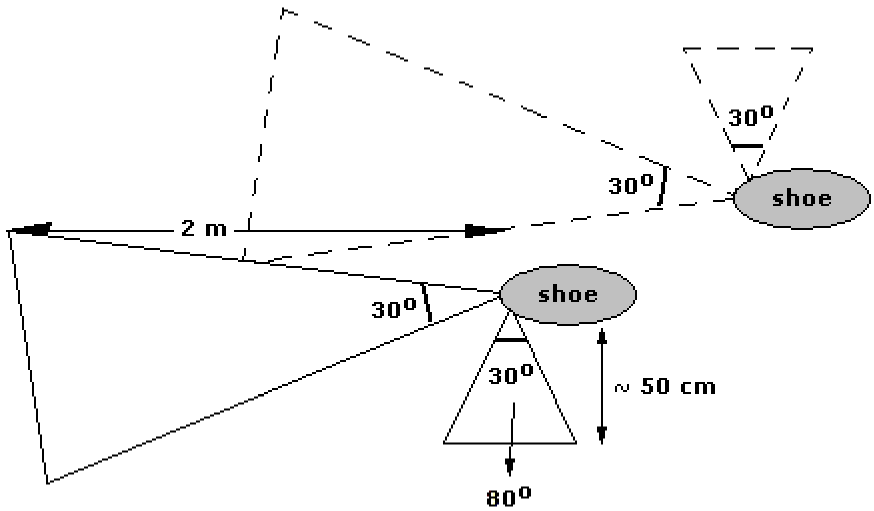

Figure 2, Location ultrasonic sensors

3.5 3D stereo vision

By request of the sponsor a ‘proof of concept’ experiment was also conducted, testing the concept of using (multiple) camera’s for the detection of objects. One experiment used 2 cameras for the creation of stereo imagery. A second experiment was performed, using only one camera and the depth of field (DOF) effect for the detection of objects.
As a result of these experiments there was concluded that it is possible to use cameras for object detection. But they have several drawbacks, like sensitive to environment changes (light, shadow, colour), not suited for continues operation while battery powered and computation intensive.

The results of the 2 experiments can be found in appendix G and H.

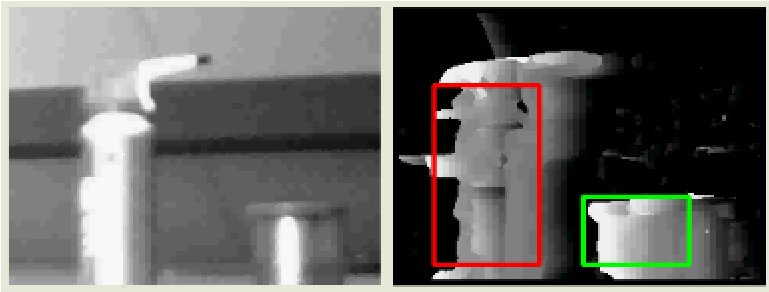

Figure 3, Object detection using stereo vision

3.6 Belt

For depth measurements from the belt to the floor we cannot use an ultrasonic sensor, because of the specula reflection. Therefore we are limited to use infrared, which has a better reflection due to its larger working angle.

Several experiments were conducted, using different measuring methods like: measuring the phase shift of the reflection and measuring the angle of the reflection. After studying their results, there was concluded that the principle of measuring a time delay (or phase angle) is not an option. With the speed of light a distance of 20 cm (2 x 10 cm) results in a delay of 0.7 ns, which is not reliably measurable with the available components

The other experiement was conducted using Sharp distance detectors[1], which are based in this principle. An experiment was conducted with a sensor that can measure a depth of up to 2 meters and has the highest resolution ($\frac{\partial V}{\partial l}$) at a depth of 40 cm (see figure 4). The results of this experiment are quite promising and definitely useful for future research.

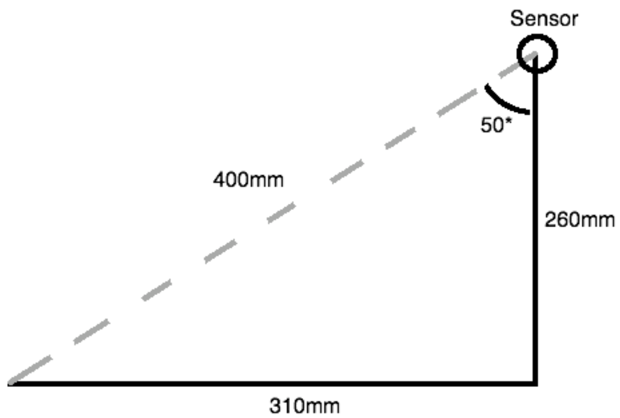

Figure 4, IR depth sensor setup

[1] Sharp GP2Dxx IR distance detector

The only problem there is, occurs with highly reflecting (mirror, polished metal) or IR absorbing (black) objects. The sensor detects these objects as going away instead of coming closer (see figure 5). Results of the experiments can be found in appendix J.

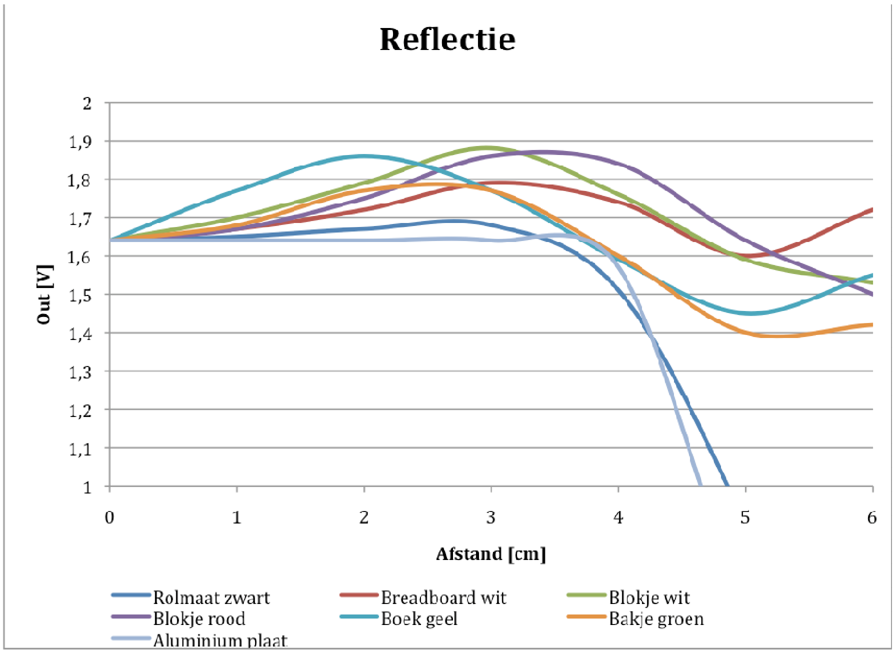

Figure 5, Reflection results

4. Implementation

Because of the limited time it was chosen, after consultation with Mr. Peters, to only build a prototype of the shoe and only conduct a pre-study for the belt. Because of this chapter 3 only contains information about the prototype of the shoe.

4.1 Block diagram

The block diagram (figure 6) gives a birds-eye view of all subsystems of the shoe.

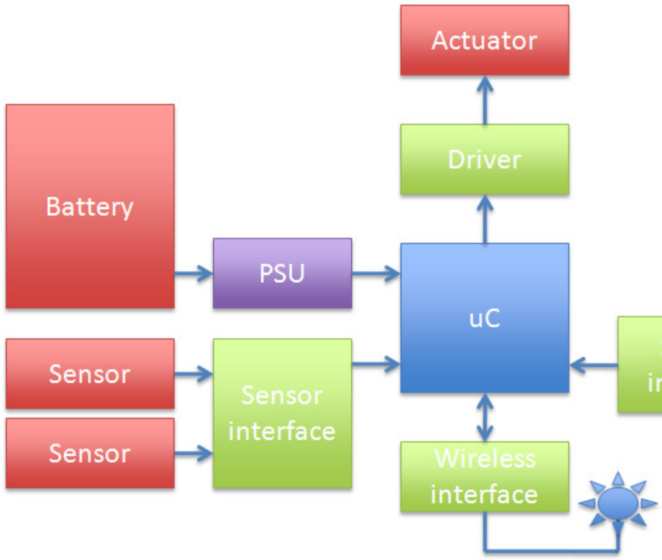

Figure 6, Block diagram

The different blocks are discussed in detail in the following paragraphs and the appendices.

4.2 Housing

To protect the electrical components against repetitive impacts, they are as much as possible intergraded in a single block (see the chambers in figure 6). The housing houses the PCB, the battery and the four ultrasonic sensors.

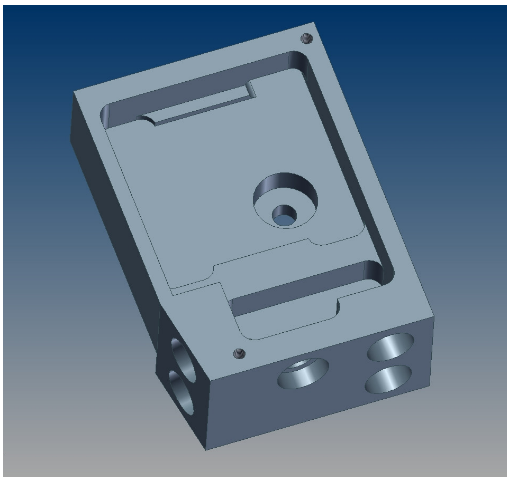

Figure 7, Overview housing

The sensors are integrated in the front and the side of the block, two in the front and two on the side (a receiver and a transceiver on both sides). The battery is located on the bottom of the block; the raised edges prevent the battery from moving during impact. The PCB is assembled on top of the battery and is screwed to the lid. The material of the lid is polycarbonate, which is transparent.

4.3 Power supply

The implementation of the power supply consists of 3 parts. One part regulates and monitors the battery voltage. The IC chosen for this part is the FAN4855. This IC has the capability to step-up the battery to +5V for the microcontroller. It also has a build low battery detection circuitry.

The second part is a regulator which supplies the wireless interface with +3V3. Again, after careful consideration the TPS60501 was chosen for this task. This IC also has the advantage of being an inductor-less step-down converter, which makes it around 50% more efficient then a linear regulator.

The third part of the power supply provides the +12V a -12V for the transmitters. After careful pondering a MAX222 has been chosen for this task. It has the advantage of being cheap, widely available and has a shutdown option to safe power. Although the MAX222 is originally designed to for the use in RS232 communication, it performs very well in our application. Being able to produce a +/-10V square wave output across our transmitter. More information about these design choices can be found in appendix F.

4.4 Objection detection

While testing the first prototype, an effect called ‘transducer ringing’ was encountered (see figure 7). This effect describes the ringing which is produced when a transducer is switched from transmitter to receiver. Figure 8 illustates this effect as an undamped transducer will ring for about 1000 cycles after switching form transmitter to receiver. This, in turn means that the minimum detectable range changes from around 10cm to 1m. That’s why there is decided to use a separate transmitter and receiver instead of a single transducer.

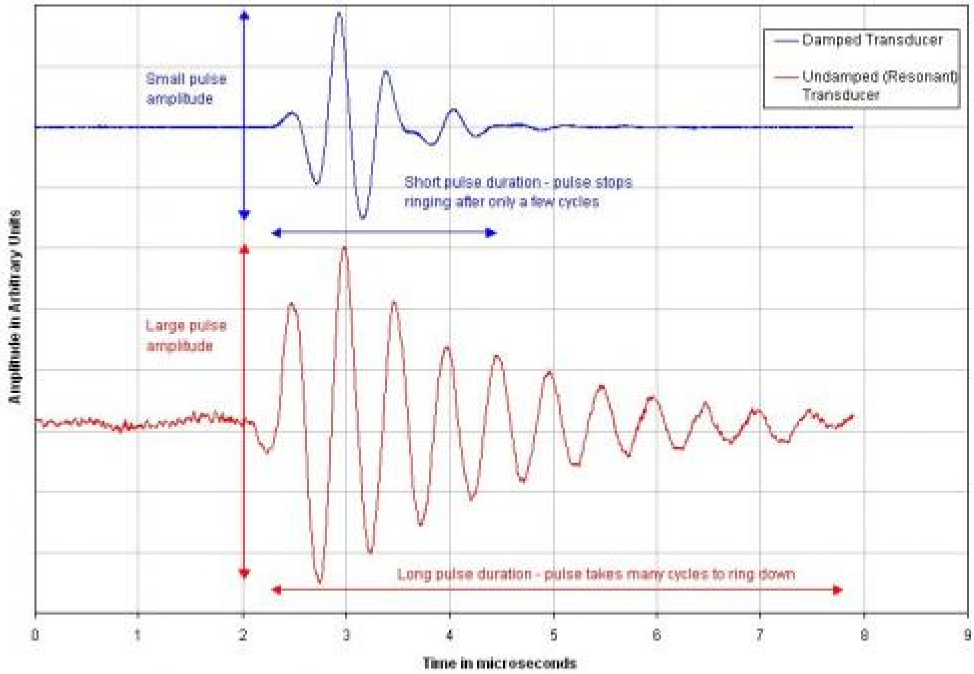

Figure 8, Transducer ringing

Three experiments were conducted on the final product to determine the boundaries of sight of the ultrasonic receiver. In the first experiment the sight in the horizontal plane has been characterized. In the second experiment the sight in the vertical plane has been characterized. This information can be used to calculate the optimal mounting angle of the sensor on the shoe. Finally, a third experiment has been conducted to determine in which degree round surfaces are able to reflect ultrasonic sound, and thus in which degree round surfaces are detectable. Results of the experiments can be found in appendix I.

4.5 Actuator

Actuators are used to inform the user about the location of possible obstacles. The sponsor provided sever different types/sizes of actuators which could be used in the prototype. After testing there was concluded that the 10mm actuators (Precision Microdrives PN 310-101) are best suited for the prototype. These actuators are both powerful and energy efficient, and thus perfect for our application.

After careful testing there was concluded that the best placement for the actuators was in the lining of the vamp. One is located on the inside (pressing against the instep) and the other on the outside (pressing against the top of the foot).

The vibration patterns emitted by the actuators are kept the same as suggested by Mr. Peters. The inside actuator vibrates when an object is detected in front of the user. The outside actuator vibrates when an object on the left/right (depending on the foot) of the user is detected.

4.6 Microcontroller

Our application required a highly integrated solution, because of its tight dimension restrictions. Because of this, main-stream microcontrollers like the ATtiny2313 and PIC16F268 were not an option. After careful consideration the Cypress Programmable System on Chip was chosen (PSoC), see appendix F for more details. This controller its main advantage is the ability to simulate analog circuits, like band pass filters and comparators, with internal OpAmps. Another advantage is the internal programmable logic. This greatly reduces the complexity of the PCB design, and so greatly reduces the cost of the final prototype.

The embedded software relies heavily on this combined analog and digital functionality in conjunction with interrupts. An overview of the software is provided in figure 9.

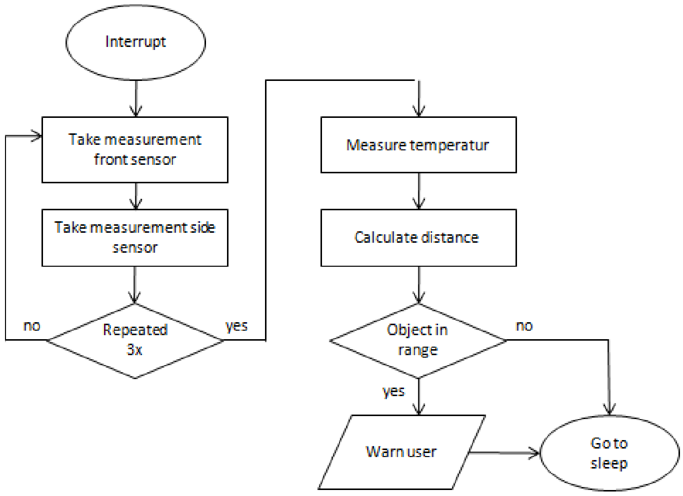

Figure 9, Program flow embedded software

An interrupt is triggered when movement is detected. Using this interrupt, 3 measurements are taking from both the front and side sensors. An average of these measurements is taken for each sensor and compared against a threshold. If an object is closer then the set threshold it activates the actuators and warns the user about oncoming obstacles.

4.7 Wireless interface

A wireless interface is used to transmit vital data between the shoes and the belt. This data includes battery status, movement, charger status, temperature, etc.
Because of the strict power requirements and limit develop time there was decided to use an nRF24l01A. These low power 2.4GHz transceivers are easy to use due the available (two-layer) reference design and abundance of C examples. More about the wireless interface can be found in appendix F.

4.8 Force sensor

In this application the Force Sensing Resistor (FSR) is used in conjunction with another resistor to form a force depend voltage divider. The PSoC microcontroller that is used has an internal comparator with an internal voltage reference. This comparator is setup to trigger an interrupt every time the voltage comes above 1.3 V (internal reference voltage). These interrupts, in turn, are used to signal the start of a new measurement (see figure 9).

4.9 Amplifiers and filters

An amplifier is required to amplify the signal from the ultrasonic receiver to a usable level. Some experiments where conduct to determine the required level of amplification. It was decided to use an amplification of 57 dB (750x).

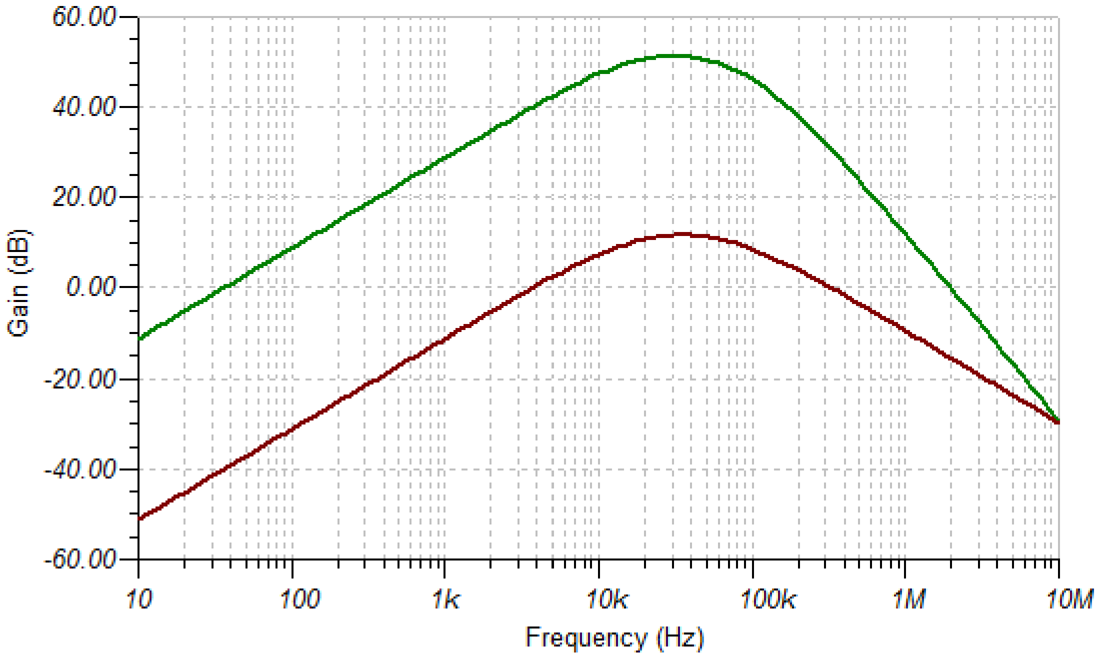

Figure 10, Filter transfer

It was also decided to use filters to limit the bandwidth of the amplifier. A first-order high-pass filter and second-order low pass filter is used for this purpose, both with their roll-off frequency at 40 kHz (see figure 10).

4.10 PCB design

The PCB design was heavily influenced by the same set of requirements as the housing (see paragraph 3.2). It also had to be small, cheap and durable. To comply with these requirements it was decided to use only SMT components and a dual-layer PCB, which is significantly cheaper than a four-layer PCB. Due to the use of SMT components the PCB had to be fabricated by an external company; EuroCircuits.

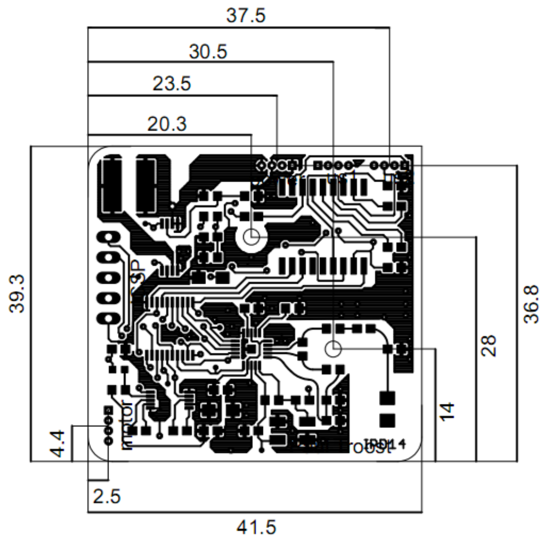

Figure 11, PCB design

Two versions of the PCB where made, as the first prototyped showed the 'transducer ringing' effect, see paragraph 4.4 for more information.
More information about the PCB design is located in appendix E.

5. Finished Deliverables

The following objectives are completed at the end of the project:

1. Conduct experiments to determine the best sensors for object detection. Sensors should be compared on properties like: accuracy, price, weight, size, power requirements.
2. Build a prototype of the shoe as described in the patent. The shoe should be thoroughly tested and recommendations should be made for future improvements of the patent.
3. Conduct experiments to determine the best sensors for depth measurements. The sensors should be able to operate reliably while the user is moving.

The results of the first objective can be found in appendix I.

The result of the second objective will be demonstrated at the IPD symposium on the 8th of June. At the time of writing this report objective 2 is only partially completed, as the object detection is not reliable. The main cause for the unreliability is noise on the supply voltage of OpAmp, which is caused by the SMPS.

Figure 12, Finished prototype

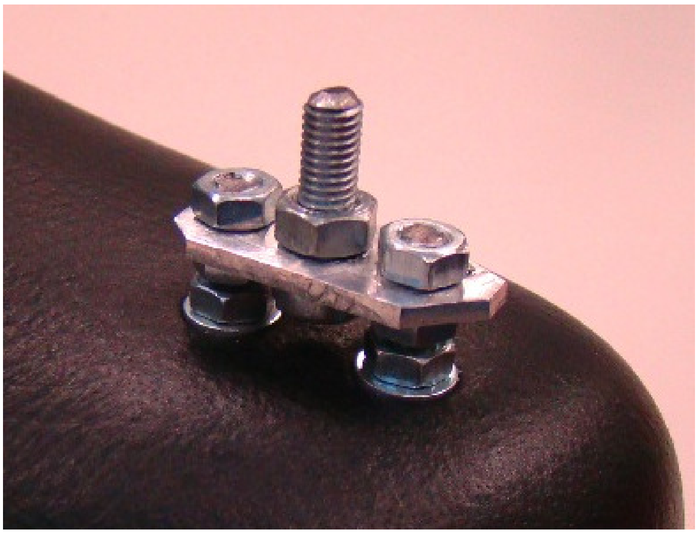

Figure 13, Finished sensor mount

The result of the third objective can be found in appendix J.

6. Conclusion and Recommendations

From the above it can be concluded that the idea from Mr. Peter is feasible. Nevertheless, it would require a lot of additional research and testing before it is ready for the real world.

The following specific conclusions can be drawn from the conducted research and building of the prototypes:

- The IR distance sensors from Sharp are suitable for measuring depth. The incorrect detection of reflecting objects is not applicable in our situation, as these materials are rarely found on a floor.

- 3D stereo vision can be used to detect object. Although, it requires a lot of (computation) power and is susceptible to false positives, caused by shadows.
- A user receives minimal discomfort from the device, when mounted on the shoe. This is largely due the (low) weight of the housing and the (limited) size of the actuators and force sensor.
- A FSR can be used for reliable measurements of user movement.
- Using a transducer can cause the 'transducer ringing' effect. This effect is best avoided using a separate transmitter and receiver.
- A PSoC microcontroller is best suited for the task of object detection using ultrasonic sensors. Its main advantage is its internal analog blocks, which make it possible to perform complex analog functions, like a comparator or amplifier, inside the microcontroller.

In accordance with previous conclusions, the following recommendations are made for future research into the subject. These recommendations only concern the finished deliverables, recommendations on the entire project can be found in the SSD and PvA.

6.1 Implementation – Electrical

Three recommendations for the electronics are made. The first recommendation concerns the power supply. It is not recommended to use an SMPS to power the analog circuitry. Even the tiniest noise on the supply voltage will be amplified by the OpAmp. It is recommended to filter the supply voltage using a linear regulator with line regulation of >80dB, or to not use an SMPS at all (powering all electronics directly from the battery at 3V).

The second recommendation concerns the microcontroller. It is recommended to use another PSoC, for example the CY8C24223A. These larger PSoCs' contain more advanced analog features. For example a PGA, BPF and SMPS. This would make it possible to integrate the external filter, amplifier and power supply in the PSoC. It is even plausible that a transducer could be used, instead of a separate transmitter and receiver, as a PGA can be used to counteract the transducer ringing effect.

The last recommendation concerns the RF wireless interface. It is recommended that a future project team researches to possibility of using a CyFi low power transceiver instead of the nRF24L01. The PSoC IDE contains readymade API functions for this family transceivers. Thus, using those transceivers would decrease the complexity of the software.

6.2 Implementation – Mechanical

For the mechanics, it is recommended to integrate the housing in the shoe. For example: placing the electronics in the midsole at the heel, and the sensors in the nose of the shoe. This would increase the comfort while wearing the device. And it would also give a better look to the device, as a user would look silly while wearing the current prototype with external housing. Additionally, the mechanical stress on the components will decrease, due to the lowered impact speed.

It is also recommended to use more sensors for object detection (4 to 6 instead of 2), as this will eliminate the need for an adjustable sensor mount. This, in turn, will greatly decrease the complexity of the mechanical design of the sensor mount.

6.3 Finance

In the area of finance, it is recommended (to the sponsor) that the budget is cut in half. Both the cost estimate and the real cost showed that a budget of €750-€1000 is plenty for building a prototype of both the shoe and the belt. Anything above this could encourage reckless spending by a future project team.

6.4 Organization

Three recommendations are made to the organization. The first two recommendations are directed toward the future project manager. It is advisable that he/she makes sure that all project members put in enough time in the project (especially in the beginning). Secondly, it is advisable that future project manager makes a realistic planning. The current project manager failed to do both these things, which resulted in a high workload and negative atmosphere at the end of the project.

The last recommendation is directed at the IPD management. It is advisable to either change the ‘order day’ of the stockroom, or to change the IPD project day. Because, it takes 2 weeks to order components in the current situation (‘order day’ on Tuesday and IPD project day on Wednesday). However, it would only take 1 week when the IPD project day is before the component ‘order day’. Thus, swapping these two days could greatly increase efficiency of the project team.

6.5 Marketing

There are no recommendations for the marketing of the device. Although, it would advisable to only focus on the marketing when there is a correctly working and thoroughly tested prototype. Otherwise, it could damage the image of the device.

7. Glossary

The following abbreviations are used in this report:

Abbreviation	Meaning
3D	3 dimensional
API	Application programming interface
BPF	Band pass filter
C	ANSI C – a high level programming language
CyFi	Family of low power wireless transceiver, made by Cypress
DOF	Depth of field
FSR	Force sensing resistor
GPS	Global positioning system
IC	Intergraded circuit
IDE	Integrated development environment
IPD	Integrated product development
IPD14	Integrated product development – project 14: '*a view for blind people*'
IR	Infra red
OpAmp	Operational amplifier
PCB	Printed circuit board
PGA	Programmable gain amplifier
PN	Part number
PSoC	Programmable System on chip, a microprocessor made by Cypress
PvA	Plan van Aanpak – Plan of Approach
PVC	Polyvinyl chloride
ROI	Return on investment
RS232	Serial communication method
SMT	Surface mount technology
SSD	System Specification Document
uC	µC – microcontroller

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