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THEIAVISION: ULTRASONIC GLASSES FOR PEOPLE WITH VISUAL IMPAIRMENT

Bachelor’s thesis (12 EAP)

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1 Introduction

According to the World Health Organisation (WHO) in October of 2013 there were approximately 285 million people in the world with visual impairment, 39 million of who are blind and 246 million whose eyesight is weak [1].

According to Stolovitch and Keeps, the average person receives 83% of information via eyesight, 11% from hearing, 3.5% from smell, 1.5% from touch and 1% via the sense of taste [2]. According to this, it is simple to see, that the most important sense is eyesight. That information goes far beyond our ability to read a book. The eyes actually possess additional functions, that some do not link directly with eyes and vision.

These functions include navigational assistance, detection of buildings, other objects and coordination such as walking on the street and not tripping or when exiting the house and upon seeing the door, opening the door and walking through the doorway, rather than walking into the door.

The goal of this bachelor's thesis is to develop a set of glasses, which would give one dimension of vision back to a blind person – the one that allows the person to identify objects, which are situated on the individuals moving trajectory and navigate the environment accordingly.

2 Overview of the field

2.1 Infrared distance sensor

Beam of light reflected off an object is reflected through another lens onto a position-sensitive detector (PSD). The conduction of the PSD depends on the location of the beam of light. Conduction is transformed into voltage and by digitalising the voltage, for example with a microcontroller's analogue-digital converter, the distance of the object can be calculated [3].

This system, however, has several drawbacks. Since light does not reflect off every surface in the same way, the reading of the sensor can differ between various surfaces or colours, even if the actual distance is the same [4].

2.2 Ultrasonic sensor

The distance of an object is determined by measuring the time it takes for the sound wave to reflect back from the object. The frequency of the sound wave is in the ultrasonic spectrum. By measuring the time it takes for the sound wave to reflect back, it is possible to calculate the distance travelled by the wave. The distance of the object is thereby half of the distance the wave travelled [5].

Since sound is a mechanical wave and in no way directly affected by sunlight, which is an electromagnetic wave, then the sensor can also be used efficiently in most outdoor conditions. Errors in readings can occur, if the object, subject to distance measurement, is sound absorbent.

One more problem with this type of sensor is "ghost echo". This is an echo, which is reflected, not off the object, whose distance we wish to measure, but off of surrounding objects, for example walls. In this case the readings can be incorrect [4].

2.3 Computer vision

Computer vision is a field of informatics, which teaches computers to see. It is a way computers gather and interpret visual information from the surrounding environment [6].

Usually the image is first processed on a lower level to enhance picture quality, for example remove noise. Then the picture is processed on a higher level, for example detecting patterns and shapes, and thereby trying to determine, what is in the picture [7].

With computer vision it is possible to, for example detect faces, buildings, characters in a text, and give an overview of the people in the room, the specific location of a person, if the person in question is located next to a building that is in the database of the system, read the text from books and with the help of additional technology have it interpreted, read out aloud or just recorded.

Additionally, computer vision is used to ensure vehicle safety, detecting pedestrians in situations where devices like the radar, do not work efficiently enough; in security systems, to detect intruders; in traffic cameras, to identify the licence plate of the vehicle; and in 3D modelling, to create models based on pictures alone [8].

2.4 Additional aids

Visually impaired people have a wide assortment of tools, and the specific choice between them depends on the needs and vision quality of the individual person. To better manage everyday life, the existence and usability of some additional devices and aids is essential for people with visual impairment [9].

2.4.1 Intelligent environment

These are physical areas, where with the use of embedded systems and information and communications technology (ICT), interactive spaces have been created, with the goal to improve and simplify various activities, improve user experience, protect the users or in any way allow for a better lifestyle [10, 11].

These environments include traffic lights with audio signals and its surroundings. Since a blind person cannot see the different colours in the traffic lights, the information has to be relayed differently.

These methods may include any of the following:

- Via vibrations, for which the user would have to physically touch the system,
- On a receiver-transmitter basis, which assumes that the user has a specific receiver, through which the required information is relayed,
- Via audio signal, which means that a specific sound is generated for the period, when crossing the street is safe [12].

This kind of intelligent environments are great help for the visually impaired to navigate the environment, but in reality, to make each point in the world intelligent is rather difficult.

2.4.2 White cane

White cane or a cane for the blind is the main aid for a visually impaired person, which allows for the individual to navigate the environment independently. To choose a suitable white cane, the vision quality of the specific individual must be taken into account:

- Person, who is completely blind or whose visual remainder is too low, needs a long and sturdy cane with a solid construction to be able to navigate independently. Such a cane is used to feel the surface of the road, find the obstacles and specific characteristics of the road to navigate it better.
- Person, whose eyesight is poor, but whose visual remainder is high enough to allow for independent navigation, needs a shorter and lighter cane. This type of cane is foremost a sign for surrounding people about the visual impairment of the user [13].

2.4.3 Augmented reality glasses

These are glasses, with which to combine the real world with the virtual one by enriching the real environment with information gathered from various sensors.

This information may include any of the following:

- Sound – by hearing a certain sound the device instructs the user to stop;
- Video – by using computer vision and all its capabilities;
- GPS data – by helping a blind person to better manage the trajectory while walking on the streets [14].

By influencing the reality in this way it is theoretically possible to create a situation, where a blind person can navigate the environment as well as or even better than a person without visual impairment.

2.5 Existing technical designs and solutions

2.5.1 OrCam

OrCam device [15] is a small camera, which is meant to be connected to the frames of the glasses and is connected to a handheld computer via a cable. The part of the system that is meant to be connected to the glasses, is connected with a small magnet and uses bone conduction to transmit clear audible sound to the user’s inner ear, without muffling other sounds in the environment. An image of the OrCam device can be seen in Fig. 1.

The device's capabilities include reading, recognition of faces, objects, places and products, identification and differentiation of bus numbers and traffic lights.

Fig. 1: OrCam device [15]

The apparatus has an intuitive user interface that independently understands many of the user's desires. Faces and locations are tracked in real time and the user is immediately notified, if a familiar person or place is recognised, without the need for user interaction.

The device can also learn something new, such as a place, face or an object. To teach it something, simple procedures such as waving or shaking must be detected to inform the device that new information will need to be saved [15, 16].

The system is no doubt beneficial to people with visual impairment, but unfortunately it cannot warn the user of objects that may lie ahead, which could mean that the person walks into a wall or other obstacle, thereby causing oneself physical harm.

Another detail that is in disfavour of the device is the price. The system costs $2500 [15], which is equivalent to about €1840. In comparison, the Estonian average income per month in the second quarter of 2013 was €976, which makes for a net income of about €770 [17, 18]. In other words, the average Estonian would have to work for approximately 2.4 months to be able to afford this device, assuming that 100% of income would be kept for the glasses and nothing else.

2.5.2 GlassUp

GlassUp [19] is a device that looks like a normal pair of glasses. Despite its discrete appearance, the device is very practical. It is able to display SMS messages, navigation instructions, Facebook and Twitter updates, calendar events, real time feedback during various sporting activities, subtitles for movies, displaying translations to movies, displaying translations to a foreign language and descriptions of exhibits in museums. A photo of the GlassUp device can be seen in Fig. 2.

Fig. 2: GlassUp device [19]

GlassUp projects the displayable information in the center of the field of view, which reduces strain on the eyes, compared to, for example Google Glass, where the information is shown on the side. This type of approach is also helpful, if the user has been diagnosed with tunnel vision, glaucoma or even migraine [20, 21].

Additionally, GlassUp can only receive information, meaning it is not able to record video or take pictures. This is a fairly great deficiency, taking into account that for Google Glass, the user need not take their phone with them, whenever they might need or want the additions of augmented reality [19, 22].

In comparison to OrCam, the GlassUp has a much lower price, from $299 for the base model to $499 for the most expensive one. Added to all of this is of course the price of the smartphone [19].

The biggest bottleneck of all, however, is that this device is mostly seer-oriented. It might be convenient for an average person without visual impairment, but for a blind person this device is useless.

2.5.3 Google Glass

Google Glass [23] is a miniature computer system with optical display glasses. Simply put, it is a smartphone-like set of glasses that can communicate with the user with simple and natural voice commands. For this specific type of glasses, the whole system is integrated within the spectacles. Additionally, the user has the opportunity to connect the device with a smartphone, thereby increasing the capability of Google Glass [24].

Glass is also able to save images and videos, display navigation instructions, send SMS messages and display received messaged, search the internet for responses based on queries, translate words into foreign languages, play music and show calendar events [23, 25, 26].

Google Glass's biggest issue raised is the privacy and in some countries even the legality of the product. According to the current laws in Russia and Ukraine, it is prohibited to use spy gadgets that are capable of saving video, sound or pictures in an inconspicuous manner [27, 28]. There is no such law in Estonia.

At the moment, only a few people have had the privilege to purchase Glass and even so only within a special developer-oriented program. The cost of one pair of Google Glass was $1500. In 2014, Google will reportedly also start the sale of a cheaper version of Glass for the public masses [29].

The device can also assist the blind. Specifically, applications have been designed to help blind people to better understand and navigate the environment.

One of them can tell the user, what the device sees. Firstly, the user takes a picture of the object he or she wishes to identify. Then the photo is shared with the application, which forwards the image to either the Twitter social network or Amazon's Mechanical Turk [30] environment. If a reply is received, then it is read back to the user. The drawback of this system is, however, that depending on the current time and the object to be identified, it is a possibility that the answer will not be provided.

Application "Memento" allows the user to save a description about a photo or a scene. When a person with visual impairment who is using Glass walks to the previously saved place, Google Glass recognises it and reads back the description [31, 32].

2.5.4 Yanko Design

Yanko Design's homepage [33] contains several designs of devices that could assist people daily. Unfortunately, it is mostly only designs, meaning there are no such devices for sale.

2.5.4.1 Blind Stick with Eyes

On first glance, it looks like a normal white cane for the visually impaired. On closer inspection, however, it is far from it. A sensor has been fitted onto the lower part of the cane, which can understand, if the user is nearing a staircase or traffic lights. If this is the case, the cane informs the user of this with vibrations [34].

2.5.4.2 Lightsaber cane for the sight impaired

It is a scientifically enhanced and improved version of the white cane. The lightsaber cane, also known as the Eye Stick, uses ultrasonic sensors to measure the distance of objects, thus helping the user to navigate the environment safer and more efficiently. Thanks to the use of ultrasonic sensors, the reliability of the device is not affected by rain, fog or other similar factors [35].

The lightsaber cane is also capable of identifying products in a store by scanning the bar code with the built-in camera. Information is sent through a Bluetooth connection to headphones, where the user receives an audio summary of the specific item [36].

3 TheiaVision

3.1 Overview of concepts and conventional technology

3.1.1 LDO

A low-dropout (LDO) regulator is a system, which is used to provide and maintain a steady output voltage, while operating at a very small input-output voltage difference. This voltage difference is called dropout voltage [37].

While standard linear voltage regulators can need as much as 2 V higher input voltage, than the required output voltage, an LDO regulator needs much less headroom to function [37].

For example, if 5V is the required output voltage, the minimum input voltage at which the standard linear regulator can still function properly and provide the necessary output, would have to be at least 7V. This can be acceptable in applications, where the input voltage is much higher than the required output. However, if the system is powered by a regular battery and requires the dropout voltage to be as low as possible, then the standard regulator will not be sufficient.

Meanwhile, an LDO regulator can have dropout voltages lower than 100 mV, thus making it a suitable choice for such applications [37].

3.1.2 Supervisory circuit – voltage detector

Supervisory circuits are electronic devices that detect and monitor the voltage levels or other system parameters in power supplies, various microprocessor applications and other systems.

When thresholds set by the user or manufacturer of the circuit are exceeded, the supervisory circuit takes appropriate action to protect the monitored system.

One of the functions of this type of circuit is power-on reset (POR) protection for a microprocessor. This feature ensures that the device starts operating in a known state.

Another application of the supervisor can be under-voltage protection. This can range from a simple low-power warning to a complete shutdown of a system to maintain the integrity and longevity of the monitored system.

Supervisory circuits are also known as power supply monitors, reset circuits, supply supervisory circuits and battery monitors [38].

3.1.3 Diode

A diode is a device that conducts electricity perfectly in one direction, which is called the forward direction, but acts as an insulator for the other direction – reverse direction. Real world diode behaviour is somewhat different than that. Diodes consume some power when forward current is applied and will not perfectly block all reverse current [39].

Perfectly ideal diodes do not exist. However, a nearly ideal diode does exist. It means that it is configured to have an ultra-low current flow in reverse direction, very low forward impedance and thus a very low forward voltage drop [40].

Ideal diodes in a diode-OR configuration offer a simple way to switch between multiple power sources and also isolate the power sources from each other. The diode-OR configuration means, that the output is driven high if at least one of the inputs is a logic one. If none of the inputs are high, then the output is a logic zero, meaning no current flows to the output [41, 42].

The isolation of supply units is also necessary. This is to prevent current flow from one unit into another, thereby reverse biasing it, which could cause the component to malfunction. Additionally, without the isolation, the short of one power supply could lead to the short of the combined output of the two supplies. Reliability can be a problem when using diodes in a diode-OR configuration. If one of the diodes were to fail, then the whole OR system might fail. In order to amend the issue, transistors are often used in their place [43].

3.1.4 Microcontroller

Microcontroller is effectively a small low-cost computer on a single integrated circuit built for dealing with specific tasks. It usually contains a central processing unit (CPU), read-only memory (ROM), random access memory (RAM), and input/output ports [44].

Microcontrollers are sometimes confused with microprocessors. However, the two terms are not equivalent. A microprocessor is used to execute large generic applications and tasks, such as with the use of a personal computer, and usually contains only a CPU. A microcontroller on the other hand usually contains all the above mentioned components and is built to execute a specific task, such as receiving data from a remote control for a television.

3.1.5 Resettable fuse

A fuse is a passive electronic component used to protect an electrical circuit against excessive current [45].

Regular fuses are one-time devices. It will provide overload protection only once, after which it will need to be replaced. Within a traditional fuse is a metal element, which is heated by current flowing through it. The higher the flowing current, the higher the temperature achieved. If an excessive amount of heat is achieved, the element will melt and the current flow decreases to zero. The fuse itself is, however, destroyed.

A resettable fuse also reacts to excessive current, but unlike a traditional fuse, it is resettable. This means it can provide overcurrent protection several times. When the component experiences overload, it gets heated and the resistance of the polymer within the resettable fuse increases. Thus, the current flow is limited. The device resets itself when the power source is removed.

The scientific name for a resettable fuse is polymeric positive temperature coefficient device (PPTC) [46].

3.1.6 Sound generators

Although buzzers and sound transducers are both used for sound generation, they are not interchangeable terms. If the sounder is driven by an external oscillator, then it is called a transducer. If a built-in oscillating circuit is used, it is called a buzzer [47].

Electromechanical transducers incorporate a permanent magnet, wound coil, metal diaphragm, yoke plate and a pole. When a voltage is applied to the pins of the device, a magnetic field is generated by the coil. This causes the magnet within the device to move and a metal diaphragm that is attached to it to vibrate up and down. This creates air pressure waves that are better known as sound. The problem with this type of transducer is that since it uses electromagnetism to create a sound, it also generates electromagnetic interference (EMI).

Piezoelectric transducers incorporate a thin piezoelectric ceramic connected to a vibrating metal disk. When a voltage is applied, the ceramic and the metal disk vibrate together as one, with the piezo ceramic physically flexing with respect to voltage. The metal disk acts as a diaphragm producing air pressure waves that the human ear interprets as sound. Since there is no magnet within the device and also no electromagnetic waves emitted, this type of transducer has no EMI problems [48].

3.1.7 Pull-up resistors

Pull-up resistors are used to provide a definitive state to an input pin. A pull-up resistor is connected between an input pin and the positive power supply pin (also known as V_{CC}, V+). If it were to be omitted, the state of the input pin would be unknown. This is known as floating.

Floating pin means that the voltage level of the pin can be anywhere within V_{CC} and ground (GND). This in turn means that the pin can randomly range from a logic one to a logic zero [49].

3.1.8 Pulse width modulation

Pulse width modulation (PWM) is a way to vary the average amount of power that is transferred to the output, usually accomplished with the use of a digital device, such as a microcontroller. Since a digital device can only generate two levels of output, a logic one and a logic zero, the output signal that is generated is actually a modulated version of a square wave. This can be achieved by changing the frequency and duty cycle of a signal.

Duty cycle is a percentage of the time signal was high relative to the full clock cycle. Frequency is the rate at which the signal goes low and high.

By changing the duty cycle, it is possible to generate any voltage between GND and V_{CC}, as this generates the same percentage of input voltage to the output. However, the frequency of the signal must be high enough for this to work effectively. Otherwise the output would just be high and low, instead of the desirable voltage [50].

3.1.9 PCB

Printed circuit board (PCB) is a thin board usually made of fiberglass or composite epoxy and is used for physically supporting and electrically connecting various electronics components that make up an electrical circuit. The lines interconnecting various components are called tracks [51].

Before the PCB was invented, circuitry was constructed with point-to-point wiring. However, this was not a sturdy system, due to the fact that this led to frequent short circuits and wire failures due to aging and long-term deterioration.

Another alternative to PCB has been wire wrapping, where a small wire is wrapped around a small pole at each junction. However, with the constant need to reduce the size and manufacturing costs of electronic devices, the use of wire wrapping has lessened over time [52].

3.2 Functional description

The system actively monitors its surroundings by measuring the distance of objects around it via ultrasonic sensors. The distance is measured separately on each sensor, as they work independently of each other.

The minimal safe distances set for the sensors can be seen in Fig. 3.

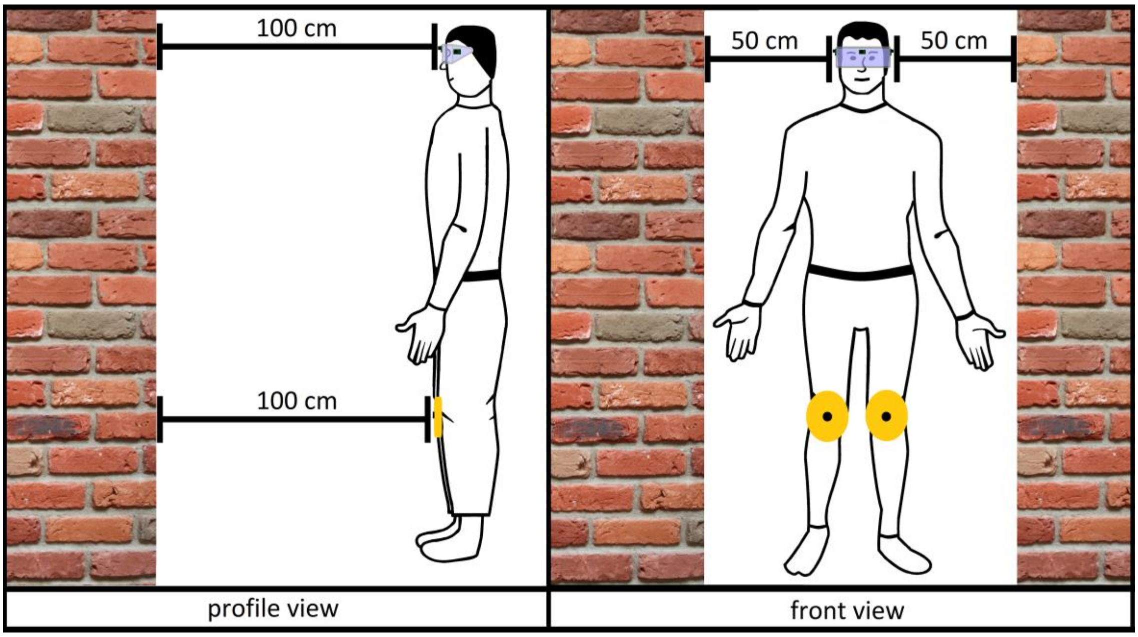

Fig. 3: Minimal safe distances on TheiaVision

The term minimal safe distance means the minimum distance of an object from the sensors, which is considered safe by the system. If the distance of any detected object is less, the corresponding alarm will be sounded.

The sound generators are connected to the microcontroller output compare unit pins and the audio signals are generated via pulse width modulation. Since the unit allows for the easy change of both the duty cycle and the output frequency, the signal can be easily created on the specific pin, thus generating the sound via the transducers.

The core of the system, the motherboard and the batteries will be attached to the upper arm or belt of the user, so that it would be close enough to clearly hear the alarm if any are sounded, yet far enough to disturb the normal interactions of the person using it as little as possible.

There are five sensors used within the system: three of them are connected to the glasses and the remaining two are situated on the knee braces – one on each knee. A graphic overview of this arrangement can be seen in Fig. 4.

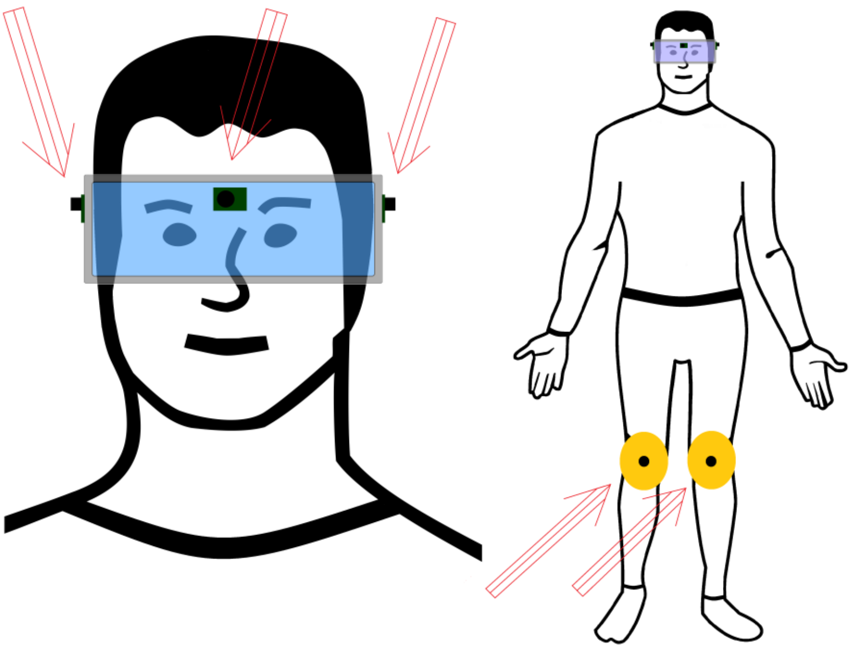

Fig. 4: Graphical representation of sensor positions

3.3 Electronics design

3.3.1 Supply power management

The system is meant to be powered with two Lithium-Ion (Li-ion) rechargeable batteries connected in a series. The batteries themselves were made for the Samsung S3 i9300 cellular telephone. Each of the batteries has a maximum output voltage of 3.8 V, thereby giving the whole system a maximum power input of 7.6 V. The capacitance of one battery is 2100 mAh, therefore making it also the capacitance of the whole battery pack [53].

There were several reasons why Li-ion batteries were chosen over other types. The main reason was the high energy density that they provide. For a system that has to work throughout a busy working day without interruptions like time-consuming charging, maintaining a relatively small size and long battery life is a beneficial goal to achieve.

An additional benefit of the Li-ion cells is that their rate of self-discharge is much lower when compared to nickel-cadmium (NiCd) or nickel-metal hydride (NiMH). This means that they lose less of their charge over time, which in turn means they need to be charged less and the total system uptime is thereby extended [54].

The hardware configuration is fairly simple, as shown in Fig. 5. Two batteries are inserted into a special receptacle, which connects the batteries to each other (in series). The special spring loaded clasps make sure that the batteries are securely fastened within the container.

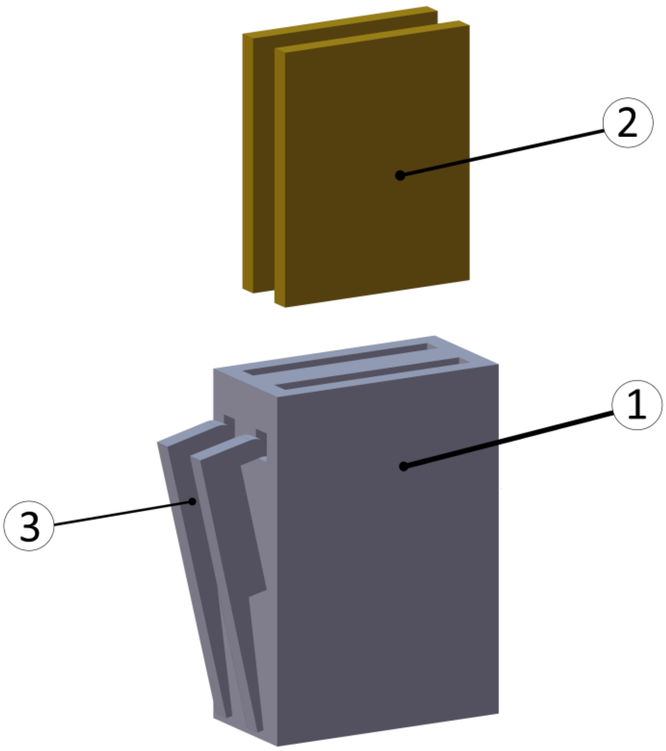

Fig. 5: Battery pack of TheiaVision
part 1 – overall container, part 2 – batteries, part 3 – spring loaded clasps

Since the batteries will need charging at one point in time, they can easily be removed from the whole system by simply releasing the clasps. This allows the batteries to be recharged and then reconnected without hassle.

If the whole system needs to be used for a longer period of time than the batteries would allow, for example so that extensive testing could be conducted, then a USB power connector is also available.

3.3.2 General design

The system board has a compact design. This is due to the desire to make the whole device as mobile as possible. Also, since the PCB is fairly small, the manufacturing costs are lower.

As the maximum tolerance of several components such as the microcontroller, is less than the output of the power supply unit when it is fully charged, the voltage has to be lowered to fit the needs of the system. For this, an LDO regulator is used to lower the voltage to 5 V. This voltage was chosen due to the fact that it is the minimal voltage at which the sensors function and the maximum at which the microcontroller still works.

Obviously, with both the active and non-active usage of the system, the batteries are drained. However, Li-ion batteries should never be drained below their minimum voltage, which is 2.4 V to 3.0 V per cell. Depletion beyond this point may damage the battery, rendering it unusable [55].

For this reason a voltage detector Rohm Semiconductor BD4860G-TR as a supervisory element was added to the design. Since two batteries are used, the lowest tolerable voltage limit is 6V. This component checks if the input voltage of the system is less than 6V. If it is, then the LDO regulator is shut down. Since the system itself will not deplete the batteries any further, the only drop in voltage will be due to self-discharge. If the voltage is over 6V, then the LDO will function as usual, providing 5V to the output.

The system can also function purely on the power supplied by the USB connection. This is achieved with the help of an ideal diode, which ensures that the power sources - batteries and USB power supply, are isolated from each other.

The actual measuring is done with five SRM400 [56] ultrasonic ranging modules. The optimal distances for the sensors are from 25 – 150 cm, but experiments have shown that they also function at a slightly shorter distance. The sensors have pins for V_{CC} and GND and one IO pin, which is used to start the measurement and also read the echo response.

The system also includes various status pins to assist in debugging, sound transducers and IO pins meant for short term future development of the system.

The schematic and PCB designs are shown in Fig. 6 and 7.

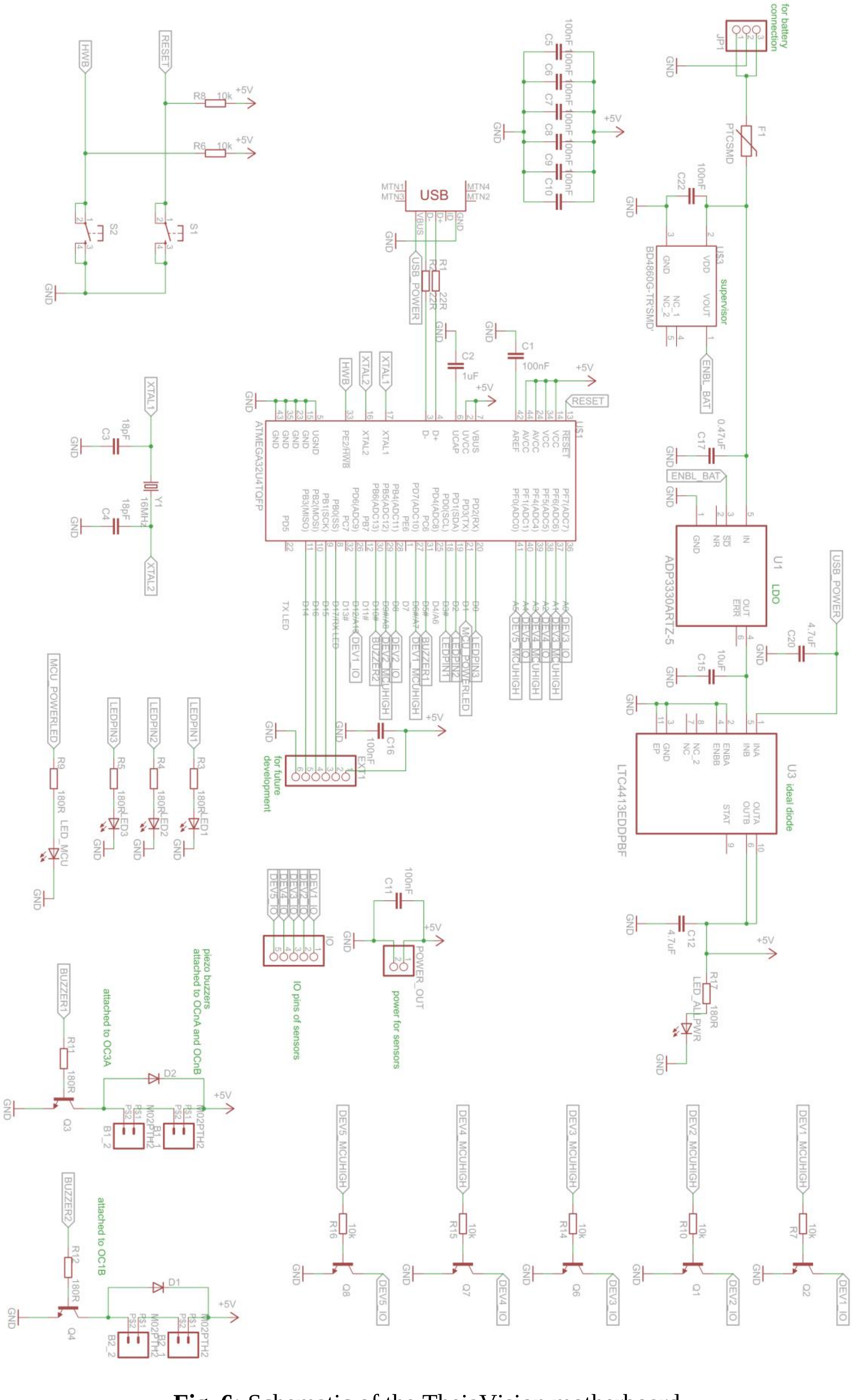

Fig. 6: Schematic of the TheiaVision motherboard

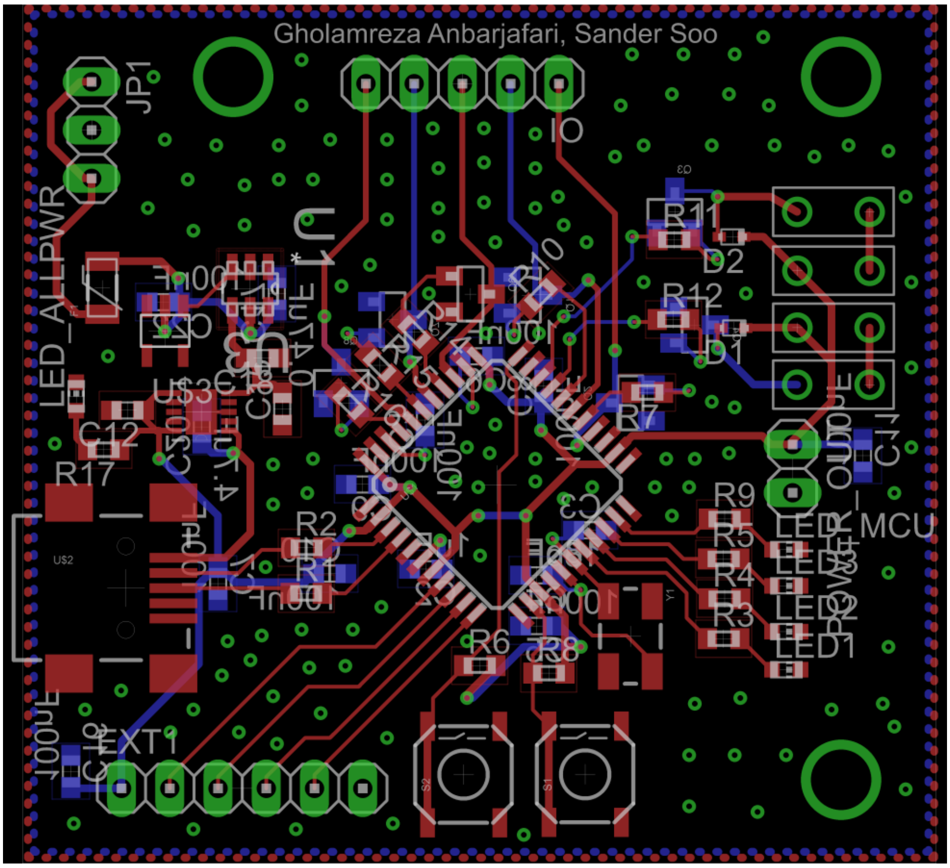

Fig. 7: PCB design of the TheiaVision motherboard

3.4 Program design

The program has a fairly simple structure. Firstly, the initialization of the hardware and program variables will occur. Upon completing that task, the system will begin to monitor the surroundings. It will send out an ultrasonic pulse and wait for a response. If the response is received and it shows that any detected object is too close, an alarm is sounded in order to warn the user. If the object is far enough, meaning either all detected objects are further than the minimal safe distances or the time that has been spent waiting for a response has been reached, the reading is regarded as being over the safe distance and no alarm is sounded. The source code of the programme is included in Appendix A. The behaviour of the program is also illustrated on Fig. 8.

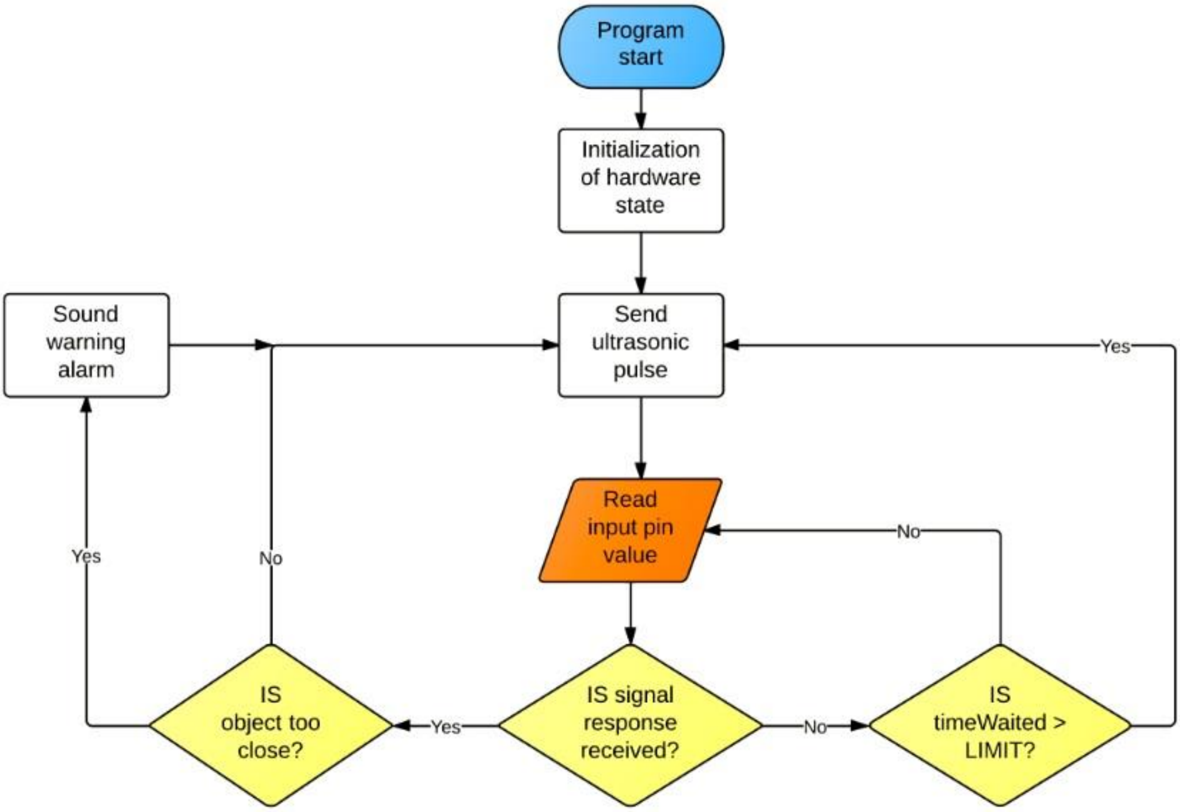

Fig. 8: Algorithm of the program as a block diagram

4 Experimental results

The performance of the TheiaVision device is briefly analysed based on a range of experiments.

The most important function in experimental testing is of course to minimize both the false positive and false negative readings. If the device is supposed to sound an alarm but in fact does not, then the person using it is more likely to hurt oneself, because he/she is assuming that whenever an object is too close, a warning would be issued. If the device is constantly issuing false alarms, then the actual alarm will more likely be overlooked.

The experiments were conducted with a rather small group of 10 people. Every test was done in two parts. The first was the control, meaning no assistance was provided at all. During the second part, all participants were using the TheiaVision system. The tests themselves were rather simple: an extremely dark room with obstacles. To minimize the effect of memory, during each test, the positions of obstacles were changed.

The tests revealed, that when the knee braces were positioned exactly on the knees or a bit lower, then during the tests, the sensors on the knee braces gave some false positive signals – people expected an obstacle, where there was not. This was due to the bending of the knees during a step, which pointed the sensors towards the floor, which caused an alarm.

After this test, the knee braces were positioned slightly higher, so that upon bending the knee, the change of the sensor directions would be minimal.

5 Benefits for the visually impaired

People with visual impairment can go through quite an ordeal every day, from finding the right banknotes in the store to pay for goods to navigating the streets. The device in its current form will probably not be very helpful when it comes to helping people with finding banknotes in a wallet. It can, however, help with the navigation.

When a blind person is trying to get from point A to point B, then inevitably, he or she must rely on some form of aid. This can be anything from a memory of various sounds occurring on the path taken or a series of left-right-straight recollections to an actual assistant to help with the navigation. However, in today’s environment there can never be 100% certainty that there will not be any deviations from the normal everyday mode of operation.

This project can help people with vision disorders to walk easier by helping them detecting the obstacles, which are placed on their way. This project can make the navigation a bit safer and less prone to possible injuries that could occur by unsafe surroundings. Remarkably, this simple feature is the one that is not present in several augmented reality products.

Additionally, it also helps the people with visual impairment to better blend into the environment. Many of these people have said that one of the most tiresome and tedious ordeals they have to deal with are people treating them like they are helpless and unable to do even the simplest of tasks [57]. This apparatus can hopefully help alleviate this problem, taking into account the discreet look and relatively small size of the device.

6 Future work

The possibilities to further advance the project are vast.

6.1 Power management

One of the simplest additions that can be made is a battery warning signal. Currently, when the system reaches the point when the batteries have been depleted to a very low level, then the connection from the batteries to the device is disconnected. This can lead to a potentially hazardous situation, due to the fact that there is no warning signal or shutdown signal sounded before the shutdown occurs. One way to accomplish this would be to add another voltage detector to the device, which will have a slightly higher threshold voltage. By reading the value of this pin by using the microcontroller, the person can be warned about the impending shutdown of the system.

6.2 Speech aided navigation

An additional feature would be the use of actual words for the system to communicate with the user. This would allow for a much more versatile user interface, thereby allowing the user to receive much more data about what is happening around him or her. The responses could be saved onto an SD card and read back to the user when necessary. The communication between the SD card and the MCU could be accomplished via the SPI data link.

Voice commands could also be integrated within the system. If the user were to find himself or herself in a situation, where the distances set in the factory are too strict, then he or she could easily fine tune the settings and personalize the TheiaVision experience to fit the current situation. Every settings change would of course be verified to prevent accidental changes.

6.3 Wireless communication

Additional feature that would be quite beneficial is the wireless communication between the various sensors and the central controller. This would make the appearance of the whole system less cluttered and more modular.

6.4 Debugging

The usage of an SD card in the future for speech processing with the system can also serve other benefits. For example, it can be used to store error codes that might occur during rigorous use. These error codes would be stored locally to the SD card and later sent to the developer(s) of the system. This would be a great aid in locating the source of various bugs and swiftly fixing them, thereby improving the user experience.

6.5 Image Processing

A higher level of engineering would be required to add such features as image processing. The idea is to have images captured and analysed in real time and faces of various people the camera sees extracted. If the face is in the database, the user is informed who he or she is looking at. If the face is not in the database, the user can add the name to the face by saving it to the database. In parallel with the facial recognition, the facial expression of the face from the captured image is also analysed. This would allow the user to interact with other people more easily and effectively.

6.6 GPS based navigation

Another module to add could be the GPS unit. Not only would it provide the usual location data and directions, but also provide a central system to collaborate with other TheiaVision users. This would mean that if one user were to encounter problems on a specific street, then other users near that same street would be warned of the problems that may lay ahead. The interaction with the central system could be realized with the use of a smartphone and Bluetooth connection between the phone and TheiaVision. An alternative would be to include mobile internet within the system.

A different locational system could also be integrated within the system that would help the blind person to find the device more easily. It could be realized with an inconspicuous remote control within a necklace or wristwatch or even a voice command with a special key phrase, upon which the system would sound a beeping signal or verbally say something to let the user know in which direction the system is located. An automatic shutoff of this feature would be in effect if the TheiaVision device is already in use. When the user shuts down the system, this feature would automatically be turned on. The two systems would of course be running on different power sources to make sure the standby system will not deplete the batteries of the main system.

7 Conclusion

There are a lot of people living in the world, whose eyesight is either very poor or who cannot see at all.

People with visual impairment have a wide variety of tools and other resources available to them. The exact choice depends on the specific needs and vision remainder of the individual.

However, most of these devices have some form of disadvantage to them, whether it is high price or the fact that they are mostly seer-oriented, with only some applications to expand their capabilities to also make them helpful to the blind and visually impaired community.

TheiaVision is a system that was developed in the course of this thesis, which actively monitors the immediate surroundings of the individual with the help of ultrasonic sensors. Based on the measurements obtained, the system warns the user of obstacles that are in a too close proximity, thus helping people with vision disorders navigate the environment a bit easier.

The system can be developed further by adding various features, such as GPS navigation and voice commands, to further simplify the life of the user.

8 Tributes and acknowledgements

I was quite fortunate to have Prof. Alvo Aabloo and Asst. Prof. Gholamreza Anbarjafari as my supervisors. They both provided me with valuable advice and guidance but also allowed me to study and explore various ideas independently.

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9 Kokkuvõte

TheiaVision: Ultrahelianduritega prillid nägemispuudega inimestele

Sander Soo

Maailmas elab palju inimesi, kelle nägemisvõime on väga halb või kes ei näe üldse.

Nägemispuudega inimestele on olemas mitmesuguseid instrumente, et neid igapäevaselt abistada. Täpne abivahendi valik sõltub konkreetse indiviidi vajadusest ja nägemisjäägist.

Enamikel neist seadmetest on aga teatud puudus, näiteks kõrge hind või see, et nad on enamjaolt nägijatele suunatud, mis tähendab, et nende kasulikkus nägemisvaegustega inimestele tuleneb vaid mõnest neile loodud rakendusest.

TheiaVision on süsteem, mis loodi selle bakalaureusetöö käigus. See jälgib järjepidevalt kasutajat ümbritsevat keskkonda ultraheliandurite abil. Vastavalt anduritelt saadud mõõtmistulemustele hoiatab TheiaVisioni süsteem kasutajat liialt lähedal asuvatest takistustest, aidates nägemisvaegustega inimestel seega lihtsamalt keskkonnas liigelda.

Vastavat süsteemi on võimalik ka edasi arendada, lisades sellele mitmesuguseid lisafunktsioone nagu näiteks GPS navigatsioon ja häälkäskluste tugi, mis aitaksid kasutaja elu veelgi lihtsustada.

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Appendices

Appendix A: Created software

```
/*
 * GccThesisV3.c
 *  Author: Sander
 */

#define F_CPU 2000000ul
#define OVF_LIMIT 1

#include <util/delay.h>
#include <avr/io.h>
#include <avr/interrupt.h>

static uint8_t speedOfSoundCMperMS=34;
static volatile uint8_t overFlowOccured1=0;
static volatile uint8_t overFlowOccured3=0;

/*
* Gives the command to send the ultrasonic impulse on a specific sensor
*/
void sendStartPulseV3(uint8_t deviceNumber){
	switch(deviceNumber){
		case 1:
			PORTD |= (1<<PORTD7);
			_delay_us(200);
			PORTD &= ~(1<<PORTD7);
			break;
		case 2:
			PORTB |= (1<<PORTB5);
			_delay_us(200);
			PORTB &= ~(1<<PORTB5);
			break;
		case 3:
			PORTF |= (1<<PORTF6);
			_delay_us(200);
			PORTF &= ~(1<<PORTF6);
			break;
		case 4:
			PORTF |= (1<<PORTF4);
			_delay_us(200);
			PORTF &= ~(1<<PORTF4);
			break;
```

```
		case 5:
			PORTF |= (1<<PORTF0);
			_delay_us(200);
			PORTF &= ~(1<<PORTF0);
			break;
		default:
			return;
	}
}

/*
* Reads the IO pin value of a specific sensor
*/
uint8_t getIOValue(uint8_t deviceNumber){
	switch(deviceNumber){
		case 1:
			return ((PIND & (1<<PIND6))>>PIND6) & 0x01;
		case 2:
			return ((PINB & (1<<PINB4))>>PINB4) & 0x01;
		case 3:
			return ((PINF & (1<<PINF7))>>PINF7) & 0x01;
		case 4:
			return ((PINF & (1<<PINF5))>>PINF5) & 0x01;
		case 5:
			return ((PINF & (1<<PINF1))>>PINF1) & 0x01;
		default:
			return 0xff;
	}
}

/*
* Calculates the distance of an object from the measured time
*/
uint16_t getDistFromTime(uint16_t timePassedUS){
	uint32_t var=(((uint32_t)timePassedUS*(uint32_t)speedOfSoundCMperMS))/1000ul;
	if (var>UINT16_MAX){
		return 0xff;
	}
	return (uint16_t)var;
}

/*
* Returns 1 if the distance of the specific sensor if less than the minimally safe distance,
* returns 0 otherwise
*/
uint8_t isTooClose(uint8_t deviceNumber, uint16_t distance){
```

```
	if(distance<50){
		return 1;
	}else if (distance<100 && (deviceNumber==2 || deviceNumber==4 ||
deviceNumber==5)){
		return 1;
	}
	return 0;
}

/*
* Initializes the specific timer, but does not turn it on
*/
void timerInit(uint8_t timerIdx){
	if (timerIdx==1){
		TIMSK1=(1<<TOIE1);
	}else if (timerIdx==3){
		TIMSK3=(1<<TOIE3);
	}
}

/*
* Turns on the specific timer to be used during distance measuring
*/
void timerEnable(uint8_t timerIdx,uint8_t toEnable){
	if(toEnable == 0){
		if (timerIdx==1){
			TCCR1B = 0;
		}else if (timerIdx==3){
			TCCR3B = 0;
		}
	}else{
		if (timerIdx==1){
			TCCR1B = (1<<CS10);
		}else if (timerIdx==3){
			TCCR3B = (1<<CS30);
		}
	}
}

/*
* Sets both timers and overflow counters to zero
*/
void setTimersZero(){
	cli();
	overFlowOccured1=0;
	overFlowOccured3=0;
```

```
	TCNT1=0;
	TCNT3=0;
	sei();
}

/*
* Initializes the specific timer to be used for generating a buzzing sound with PWM
*/
void buzzTimerInitV3(){
	TCCR1A=(1<<COM1B1)|(0<<COM1B0)|(1<<WGM11)|(1<<WGM10);
	TCCR1B=(1<<WGM13)|(1<<WGM12);
}

/*
* Deinitializes the buzzer timer
*/
void buzzTimerDeinitV3(){
	TCCR1A = 0;
	TCCR1B = 0;
}

/*
* Turns on the buzzer timer for generating the sound
*/
void buzzTimerOn(){
	TCCR1B|=(1<<CS10);
}

/*
* Turns off the buzzer timer, stops the buzz generation
*/
void buzzTimerOff(){
	TCCR1B&=~((1<<CS12)|(1<<CS11)|(1<<CS10));
}

/*
* Calculates the OCRxA register value
*/
uint16_t getOcra(uint16_t freq){
	return ( (2000000 / (1*freq) ) - 1);
}

/*
* Sounds the buzz corresponding to a specific sensor
*/
void soundBuzzV3(uint8_t devicenumber){
```

```
	uint16_t freq=500*devicenumber+600;
	uint16_t reg=getOcra(freq);
	OCR1A=reg;
	buzzTimerOn();
	_delay_ms(100);
	buzzTimerOff();
}

/*
* Turns on corresponding status LED
*/
void statusLeds(uint8_t deviceNumber){
	PORTD&=~((1<<PIND2)|(1<<PIND1)|(1<<PIND0)); //disable all status leds
	PORTD|=deviceNumber; //enable leds corresponding to current device
}

/*
* Measures the distance with the help of timers
*/
uint16_t measureWithTimer(uint8_t deviceNumber){
	uint16_t timePassedUS=0; //time passed as us
	setTimersZero();
	buzzTimerDeinitV3();

	sendStartPulseV3(deviceNumber);

	_delay_us(225);//otherwise a jitter would occur
	timerEnable(1,1);

	while(getIOValue(deviceNumber)==0){
		if (overFlowOccured1 >= OVF_LIMIT) {
			timerEnable(1,0);
			return 0xff; // failsafe to prevent measure blocking forever
		}
		_delay_us(10);
	}
	timerEnable(3,1);
	timerEnable(1,0);

	//now IO is high
	while(getIOValue(deviceNumber)==1) {
		if (overFlowOccured3 >= OVF_LIMIT) {
			timerEnable(3,0);
			return 0xff; // failsafe to prevent measure blocking forever
		}
		_delay_us(10);
```

```
	}
	timerEnable(3,0);

	timePassedUS=(TCNT3/2);
	return getDistFromTime(timePassedUS/2);
}

/**
* Disables JTAG so can use PF* pins
*/
void jtagDisable(){
	MCUCR|=(1<<JTD);
	MCUCR|=(1<<JTD);
}

/*
* Timer1 overflow interrupt service
*/
ISR(TIMER1_OVF_vect){
	overFlowOccured1++;
}

/*
* Timer3 overflow interrupt service
*/
ISR(TIMER3_OVF_vect){
	overFlowOccured3++;
}

void main(void){
	//led DDR (mcu,3,2,1)
	DDRD = ((1<<PIND3)|(1<<PIND2)|(1<<PIND1)|(1<<PIND0));

	DDRB = (1<<PINB6); //buzzer DDR

	jtagDisable();

	//MCU_HIGH as outputs (to allow for the start pulse sending)
	DDRD|=(1<<PIND7);//dev1
	DDRB|=(1<<PINB5);//dev2
	DDRF|=(1<<PINF6)|(1<<PINF4)|(1<<PINF0);//dev345

	OCR1B=350;
	timerInit(1);
	timerInit(3);
	buzzTimerInitV3();
```

```
	soundBuzzV3(0);	//startup sound
	buzzTimerDeinitV3();
	setTimersZero();


	uint16_t distance=0; //initialize distance variable

	while (1){
		for (uint8_t idx=1;idx<=5;idx++){
			statusLeds(idx);
			distance = measureWithTimer(idx);

			if(isTooClose(idx,distance)){

				PORTD |= (1<<PIND3);

				buzzTimerInitV3();
				soundBuzzV3(idx);
				buzzTimerDeinitV3();

				PORTD &= ~(1<<PIND3);
			}

			_delay_ms(150);
		}
	}
}
```

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