Ultrasonic and Image Mapped Path Finder for the Blind People in the Real Time System

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***Abstract*—** Embedded system is a combination of hardware and software. The product implemented also uses the concept of embedded system. The device is a combination of various hardware's like Raspberry pi, ultrasonic sensors, accelero gyroscope, camera along with software written in python to serve as a base for functioning of device. The data collected from environment are location and orientation of obstacle. The data is processed by Raspberry pi and communicated to the user using headphones. Several helping aids already present though help detecting the obstacle doesn't guide the blind persons to an accurate path. The device is implemented in such a way that it provides a secure and reliable guidance to the user. It helps blind people with all sorts of deficiency and not only a certain type. People suffering with other disabilities like those which are blind along with having leg disability can also use this device. It will help him detect a danger free path even if previous information about that particular place is not known. It is a portable and cap like product which a blind can easily wear instead of carrying heavy equipment's with him. It also informs the users about environment surrounding him so that they can make an accurate decision of which way they want to go.

***Keywords*—** *ARM, Blind, Embedded System, Image, Ultrasonic Sensor, Raspberry Pi component*

1. Introduction

Technology has removed many barriers to education and employment for visually impaired individuals. Students with visual impairments can complete homework, do research, take tests, and read books. The device implemented aims to guide an obstacle free path to the blind .The device is based on embedded computing, An embedded system uses a computer to perform some function, but is not used or perceived as a computer. It is a combination of single-purpose processors known as hardware and general-purpose processors known as software that describes memories and buses, illustrates hardware or software tradeoffs using a digital camera. Software is used for features and flexibility. Hardware is used for performance.

1.1 Background

The embedded system is a base for the concepts including combination of hardware and software. The system together as a whole completes the implementation of a device. Some of the typical characteristics are that it performs a single function. It is a part of larger (controlled) system; cost and reliability are often the most significant aspects. In today's world, embedded systems are everywhere including homes, offices, cars, factories, hospitals, plans and consumer electronics. Their huge numbers and new complexity call for a new design approach, one that emphasizes high-level tools and hardware/software tradeoffs, rather than low-level assembly-language programming and logic design. An embedded system can have sensors, a sample hold circuit or A/D Converters as input and can achieve communication through UART. It uses processing units such as ASIC, Processors and Reconfigurable processors. Modern embedded systems are often based on microcontrollers (i.e. CPUs with integrated memory or peripheral interfaces),[7] but ordinary microprocessors (using external chips for memory and peripheral interface circuits) are also common, especially in more-complex systems.Embedded processors can be broken into two broad categories. Ordinary microprocessors (μP) use separate integrated circuits for memory and peripherals. Microcontrollers (μC) have on-chip peripherals, thus reducing power consumption, size and cost. In contrast to the personal computer market, many different basic CPU architectures are used, since software is custom-developed for an application and is not a commodity product installed by the end user. Both Von Neumann as well as various degrees of Harvard architectures are used. RISC as well as non-RISC processors are found. Word lengths vary from 4-bit to 64-bits and beyond, although the most typical remain 8/16-bit.

Image processing is a method to convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it. It is a type of signal dispensation in which input is image, like video frame or photograph and output may be image or characteristics associated with that image. Usually Image Processing system includes treating images as two dimensional signals while applying already set signal processing methods to them. It is among rapidly growing technologies today, with its applications in various aspects of a business. Image Processing forms core research area within engineering and computer science disciplines too.

1.2. Problem Statement

Blindness may result from a disease, injury or other conditions that limit vision. Legal blindness means that a person has vision that measures 20/200 or worse. People with complete blindness or low vision often have a difficult time self-navigating outside well-known environments. In fact, physical movement is one of the biggest challenges for blind people, explains World access for the blind. Traveling or simply walking down a crowded street may pose great difficulty. Because of this, many people with low vision will being a sighted friend for helping him or make sure the tables and chairs must remain in one location to prevent injury. If a blind person lives with others, each member of the household

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must diligently keep walkways clear and all items in designated locations. Different instruments and information they have gathered previously regarding that particular area.

2. Literature Survey

An embedded system is an electronic system that has software and is embedded in computer hardware. It is programmable or non- programmable depending on the application. It is defined as a way of working, organizing, performing single or multiple tasks according to a set of rules. In an embedded system, all the units assemble and work together according to the program. Examples of embedded systems include numerous products such as microwave ovens, washing machine, printers, automobiles, cameras, etc. These systems use microprocessors, microcontrollers as well as processors like DSPs. Embedded systems are classified into four categories based on their performance and functional requirements respectively: Stand-alone embedded systems, Real time embedded systems, Networked embedded systems, Mobile embedded systems, Small scale embedded systems, Medium scale embedded systems, and Sophisticated embedded systems.

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Image processing basically includes the following three steps.

Step 1: Importing the image with optical scanner or by digital photography.

Step 2: Analyzing and manipulating the image which includes data compression and image enhancement and spotting patterns that are not visible to human eyes like satellite photographs.

Step 3: Output is the last stage in which result can be altered image or report that is based on analysis.

Ultrasound is a type of imaging. It uses high-frequency sound waves to look at organs and structures inside the body. Three different properties of the received echo pulse may be evaluated, for different sensing purposes. They are:

- Time of Flight(for sensing distance)
- Doppler shift (for sensing velocity)
- Amplitude attenuation(for sensing distance, directionality, or attenuation coefficient)

2.1. Reflection Mode

In reflection mode, an ultrasonic transmitter emits a short burst of sound in a particular direction. The pulse bounces off a target and returns to the receiver after a time interval t. The receiver records the length of this time interval, and calculates the distance travelled r based on the speed of sound c: r = c * t which is a known formula

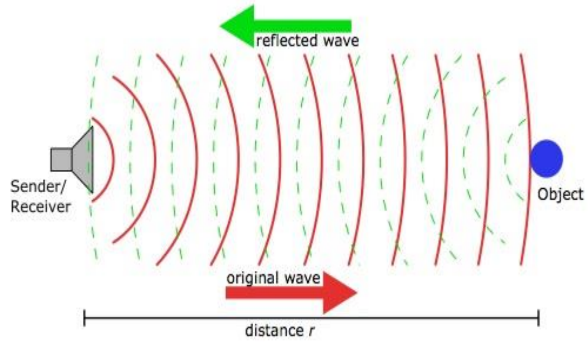

Figure 1. Reflection Mode

Very often, separate transmitting and receiving transducers are placed immediately next to each other, housed as a single unit. (The PING) Range Finder, Omega flow meter and Migatron high-accuracy sensor below are all designed this way.) In these cases, the distance calculated will be twice the distance from the sensor to the target.

Using proper coordination, a single transducer can be used for both emitting the pulse and receiving the echo. Note that it takes time for the transducer to change modes, presenting a challenge to short-distance measurement.

2.2. Direct Measurement Mode

In this mode of operation the transmitter and receiver are two separate units that move relative to each other.

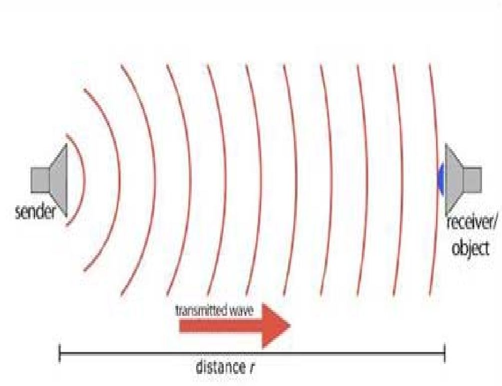

Figure 2. Direct Measurements Mod

Multiple transmitters can be used to increase the directionality of the transmitted pulse. Lima et al.3) placed multiple ultrasonic transmitters on a performer, whose signals were received by multiple receivers in the performance space, enabling a computer program to triangulate the performer's position.

2.3. Doppler Shift

When a wave reflects off of a moving object, its frequency is shifted by an amount proportional to the velocity of the object. This fact can be exploited in ultrasonic sensing by having the receiver measure not the time of flight but the frequency of the returning echo pulse. Knowing fe and fr, the frequency of the emitted and received pulse, respectively, the velocity v of the target may be calculated: $f_e - f_r = 2 f_e (v / c) \cos(A)$4, where A is the angle between the target's and the pulse's lines of motion.

2.4. Amplitude Attenuation

Ultrasonic sound attenuates much faster than audible sound when propagating through air. By measuring the intensity of the returning pulse, an estimate of the distance travelled can be made using the following equation: $I = I_0 e^{-ax}$ 5 where I and the effect of distance and angle on the amplitude of the received signal is illustrated in the following images:

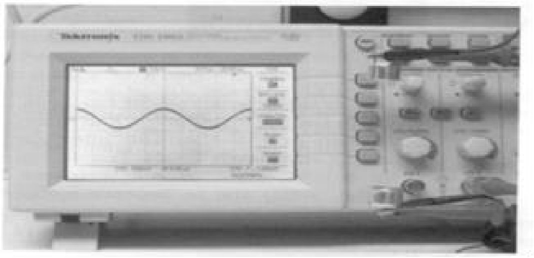

Figure 3. Amplitude attenuation graph 1

3. System Analysis

Analysis and synthesis, as scientific methods, always go hand in hand; they complement one another. Every synthesis is built upon the results of a preceding analysis, and every analysis requires a subsequent synthesis in order to verify and correct its results.

3.1. Existing System

Mobility is one of the main problems encountered by visually impaired persons in their daily life. Over decades, these peoples were using navigational aids like white cane, guide dogs etc long white cane is a traditional mobility tool used to detect obstacles in the path of the blind person. The length of the white cane depends upon height of the user and extends from the ground to the user's sternum. On the other hand, guide dogs are assistance dogs, trained to lead visually impaired around obstacles. Due to the development of modern technology, many different types of navigational aids are now available to assist the blinds. They are commonly known as Electronic Travel Aids. Although the white stick gives a warning about 1 m before the obstacle, for a normal walking speed of 1.2 m/s, the time to react is very short (only 1 s). The stick scans the floor and consequently cannot detect certain obstacles (rears of trucks, low branches, etc).

Another solution which is recently developed is Electronic Eye for Visually Impaired Persons. It is an an electronic travel aid for blind people to navigate safely and quickly. An obstacle detection system using UVC camera based visual navigation has been considered. The system is based on an embedded system eBox is a small (4.5"x4.5") low-cost X86 processor based embedded computer system. The ultrasonic sensors are connected with sensor circuit. It feeds the distance data to eBox 2300™ through a RS-232 serial cable. A USB webcam is connected with eBox 2300™ for capturing the field of view of the person, which is used for locating a human being. A headphone is connected with eBox 2300™ to get the audio feedback (beep sound) of the obstacle distance and presence of human being.The eBox 2300™ is powered by 5V, 3A DC adapter and sensor circuit is powered by two 9V alkaline batteries. The algorithms are implemented in C++ using Visual Studio 5.0 IDE, which runs on WinCE environment. The detection of human presence is carried out by detecting the human face. However there are situations, when the face is not present in the field of view of the camera in spite of the presence of a human in front of the visually impaired person.

Figure 4. Electronic Travel Aid

USB webcam is mounted on a helmet and ultrasonic sensors are placed on the user's belt. Three easy control switches are provided to control the ultrasound based distance measurement system, human detection system and motion detection system respectively. The eBox 2300™ and sensor circuit are kept in the bag which will be held on the waist of the user. The user has to operate the system manually and he/she will get the auditory feedback till the switches are pressed.

3.1.1 Advantages

The electronic travel aid has the following advantages:

- Three easy control switches are provided to manually operate the device.
- First switch is to find the obstacles in the path of the blind person.
- Second one is used to find the human presence in field of view of the camera
- The last switch is used to detect any movement in front of the person.
- The device provides auditory feedback to the user in response to the switch pressed.

Loudness of audio varies with respect to distance of object from person.

3.1.2. Disadvantages

The device has following disadvantages:

- To easily operate the device and to understand the auditory feedback, a proper training is required.
- The device is finally implemented in the form of helmet which is quite heavy.
- The hardwares used are very costly and hence it is not cost effective.
- The device needs constant engagement of hands and hence its not user friendly.
- People have to analyze the intensity of the sound to know about location of object.

3.3. Proposed system

There are many challenges in the products developed so far. The proposed system aims to resolve all those problems giving a much better experience to the users. The gadget makes use of ultrasonic sensors, embedded system and image processing concept which is portable, user friendly, modular and has a simple architecture. It makes use of Image processing concept for detecting the crowd on the way of the blind person and sending messages to a mini computer called Raspberry pi. All these components are integrated within a cap which is very light and can be easily worn by a blind person.

The gadget makes use of ultrasonic transmitter or receiver circuit which is capable of emitting short pulses. Raspberry pi is like a small computer which is used for processing and consists of RAM, input or output port, Ethernet port, USB port and CPU or GPU. Speakers are used for giving audio information. Camera is used to process the images. Battery is used to power up the entire gadget. Memory card is used to store the logs.

Testing of device is done at all the levels possible. They include:

1. Stationary object and moving device.
2. Stationary device and moving object.
3. Stationary device and object.
4. Moving device and object.

The location of object is calculated by ultrasonic sensors. The rays are emitted and sent in all directions. Once the waves come into contact with any object the rays are reflected back .these rays when received by receiver. The time difference is sent to the pi to calculate how far the object is located. The Raspberry pi is a small, light weighted and ARM based computer which consists of a GPU, memory and Operating system. The device acts as a mini computer and performs all the computations. It also stores the processed data into the memory. Once the location of object is calculated by pi using the time difference .This data along with the accelero gyroscope is used to detect the final orientation of the object.

Figure 5. Device that has been designed like a cap

- The user has to wear the device that has been designed like a cap before turning on the raspberry Pi.
- Once the user wears the cap , powers on the Raspberry Pi and starts walking by taking one step at a time, the following actions take place:
- In case the person will have to turn left and take only one step, so that device detects other obstacles.
- In case the person will have to turn left or right depending on where he wants to reach and take only one step.
- In case the person will have to go straight as there are obstacles on left and right side. He has to take two steps here.
- In case the person will have to stop right there, as all directions have obstacles

An accelerometer is a device that measures proper acceleration ("g-force"). Proper acceleration is not the same as coordinate acceleration (rate of change of velocity). For example, an accelerometer at rest on the surface of the Earth will measure an acceleration g= 9.81 m/s2 straight upwards. By contrast, accelerometers in free fall (falling toward the center of the Earth at a rate of about 9.81 m/s2) will measure zero. Accelerometers have multiple applications in industry and science. Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles. Accelerometers are used to detect and monitor vibration in rotating machinery. Accelerometers are used in tablet computers and digital cameras so that images on screens are always displayed upright. Accelerometers are used in drones for flight stabilization. Pairs of accelerometers extended over a region of space can be used to detect differences (gradients) in the proper accelerations of frames of references associated with those points. These devices are called gravity gradiometers, as they measure gradients in the gravitational field. Such pairs of accelerometers in theory may also be able to detect gravitational waves.

Once the computation of location is done, the software an optimal path is detected and given as an audio feedback to the blind. The device is also integrated with camera and battery backup .The camera is used to detect the crowd and convey about the environment so that blind person gets an idea about it. The proposed device thus overcomes all the disadvantages

4. IMPLEMENTATION

Implementation is the realization of an application, or execution. It is the carrying out, execution, or practice of a plan, a method, or any design for doing something. As such, implementation is the action that must follow any preliminary thinking in order for something to actually happen. In an information technology context, implementation encompasses all the processes involved in getting new software or hardware operating properly in its environment, including installation, configuration, running, testing, and making necessary changes. It is the action that must follow any preliminary thinking in order for something to actually happen. It is the final phase i.e. putting the system into action. Implementation is a state in the concept where theoretical design turns into working system. The most crucial stage is achieving a new successful system and giving confidence in new system that it will work effectively and efficiently. The system is implemented only after thorough checking is done and if it is found working in according to the specifications. Implementation of any software or system is always preceded by important decisions regarding selection of the platform, the language used, etc. These decisions are often influenced by several factors such as the real environment in which the system works, the speed that is required, the security concerns, other implementation specific details etc,.

4.1. Analysis of obstacle detection

The operations that have to be carried out in order for the device to detect obstacles successfully are:

1. Working of ultrasonic sensors :
   - As soon as we power up the device, the ultrasonic sensors transmit waves.
   - Once these come across an obstacle, they are reflected back to the receiver.
   - This time difference is used by Raspberry pi to calculate how far the object is located.
   - Ultrasonic sensors only detect how far the obstacle is located.
   - So we use accelero scope to find out the exact coordinate of the obstacle.
2. Working of accelero and gyroscope :
   - Accelerometers measure linear acceleration and tilt angle. They can be used to provide limited motion sensing functionality.
   - Gyroscopes can measure complex motion accurately in multiple dimensions, tracking the position and rotation of a moving object unlike accelerometers which can only detect the fact that an object has moved or is moving in a particular direction.
   - Hence accelero and gyroscopes have to be combined for accurate results.
3. Working of Haar classifiers and image processing:
   - The objects are detected using haar feature-based cascade classifiers.
   - The device can detects or recognize an object in an image by training an object classifier using haar cascades.

It is a machine learning based approach where a cascade function is trained from a lot of positive and negative images

- It creates classifiers based on training data from different object classes.
- The classifier accepts image data and assigns the appropriate object or class label.
- This feature is used to map the amount and type of crowd present ahead.

4.3. Functioning

The input to the system is takes by set of sensors connected. Five ultrasonic sensors detect the distances in left, right, middle (X2), Bottom to identify the clearance. Along with these we capture image along with the accelero and gyroscope values and are passed to the main processing unit. The inputs given by sensors are processed in 2 threads, one for handling the ultrasonic sensors and other for processing the image. The Ultrasonic sensors are sensed in round robin fashion; meanwhile the image processing involves the detection of objects using harr classifiers. These data's are coupled with accelero gyro values in order to detect the error that occurs due to the movement of the person. Based on the values of the sensors along with the result of image classification, coupled with the accelero gyro sensor the direction is effectively computed by the knowing the destination to be reached by the user.

4.4. Face tracking

Haar classifiers play an important role in image processing and in tracking faces of the obstacles on the way. The objects are detected using haar feature-based cascade classifiers. The device can detects or recognize an object in an image by training an object classifier using haar cascades. It is a machine learning based approach where a cascade function is trained from a lot of positive and negative images.

Obstacle detection using haar feature based based classifier is an approach where a cascade function is trained from a lot of positive and negative images. It is then used to detect objects in other images.Here we will work with face detection. Initially, the algorithm needs a lot of positive images (images of faces) and negative images (images without faces) to train the classifier. Then we need to extract features from it. For this, haar features shown in below image are used. They are just like our convolution kernel. Each feature is a single value obtained by subtracting sum of pixels under white rectangle from sum of pixels under black rectangle.

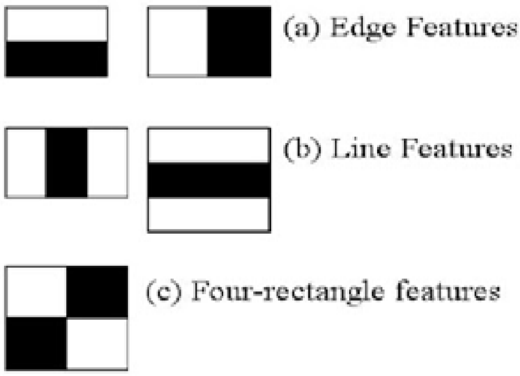

Figure 6. Various features of face detection

Now all possible sizes and locations of each kernel is used to calculate plenty of features. (Just imagine how much computation it needs? Even a 24x24 window results over 160000 features). For each feature calculation, we need to find sum of pixels under white and black rectangles. To solve this, they introduced the integral images. It simplifies calculation of sum of pixels, how large may be the number of pixels, to an operation involving just four pixels. Nice, isn't it? It makes things super-fast.

But among all these features we calculated, most of them are irrelevant. For example, consider the image below. Top row shows two good features. The first feature selected seems to focus on the property that the region of the eyes is often darker than the region of the nose and cheeks. The second feature selected relies on the property that the eyes are darker than the bridge of the nose. It is achieved by applying features applied on image classifiers.

Figure 7. Features applied on training image classifiers

For this, we apply each and every feature on all the training images. For each feature, it finds the best threshold which will classify the faces to positive and negative. But obviously, there will be errors or misclassifications. We select the features with minimum error rate, which means they are the features that best classifies the face and non-face images. The process is not as simple as this. Each image is given an equal weight in the beginning. After each classification, weights of misclassified images are increased. Then again same process is done. New error rates are calculated. Also new weights. The process is continued until required accuracy or error rate is achieved or required numbers of features are found.

Haar Cascade detection in Open CV:OpenCV comes with a trainer as well as detector. If you want to train your own classifier for any object like car, planes etc. you can use OpenCV to create one..

4.5 Ultrasonic data

The ultrasonic data for our concpet is done based on the image received from the camera and data received from accelero gyroscope, the ultrasonic data is then tested as sonic.A thread and time is imported, depending on which the related sonic data is also imported. The file of sonic data is then opened and when its true the sonic data that is generated depending on the obstacle currently detected is written and sent to the Raspberry Pi.The pulse length, calculating sonic data and resetting of GPIO settings can be done.

4.6 Face count

Just like how objects are detected in the next phase faces are detected by predefined code available in the cv library. The face count can be got by calculating the faces in front, left and right of the person.

4.7 Path detection

Once the obstacle is detected and images are got, the next step is to detect the safe path for the blind person to take. This can be chosen based on the destination to be reached by the person. The right path is chosen depending on which side is obstacle free.

4.8. Audio feedback

The data collected from various sensors is then stored in the device and an audio feedback is given to the blind person through the earphones suggesting him the free paths out of which he can choose one depending on the destination he wants reach.

5. CONCLUSION AND FUTURE ENHANCEMENT

The electronic cap like gadget implemented is to navigate visually impaired persons to reach their desired destination safely. Using this gadget is simple. By just following few small steps the blind person can walk independently in known and unknown paths without any fear of danger on the way. The major issues for users to accept these aids are they should be undestructive, easy to wear, easy to carry, user friendly and non-harmful. It should also be cost effective. Considering all these factors, the proposed system is built. User just needs to wear the cap on his head and he is all good to go.

The proposed system is superior to the previous systems implemented so far. It also helps to avoid the major accidents that might be caused unknowingly by blind people. It also helps the blind people to become more independent and secure. The reliability of the device is enhanced by camera along with two extra sensors specially for ground clearance and detecting obstacles angularly. Training time is very less. The device is more robust and space efficient. The device can be coupled with GPS to find the route and walk efficiently to reach the destination. It also tells about the environment surrounding him, so that he can make correct decisions depending on where he had planned to go.

This prototype can be enhanced in following ways:

i) Audio based feedback can be extended to regional languages so that it can be easily understood by the user without the need to learning a new language. This is done through natural language processing.
ii) An android application can be designed for navigating the path for the user.
iii) The device can be coupled with GPS to discover more accurate route.
iv) Analyze the environment more accurately.
v) Use high level camera for clearer detection of objects and high level battery for long life.

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