Embedded System Using Ultrasonic Waves and Voice Biometric to Build an E-Glass for the Blinds

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Abstract:

Currently, embedded and real time systems are used in wide range of a related human applications to improve the quality of our lives such as embedded systems for communication (Mobile, satellite, and avionics systems), and control systems such as (microwaves, refrigerators and embedded system in vehicles). Nevertheless, embedded and real time systems are still immature. The application of these systems is used for various devices. However, these systems are never used for a human body to complete human missing-part functionality; which means the embedded system can be used as part of natural neural networks in a human system nerve. This paper proposes a technical view to build an electronic glass (E-Glass) for the blind people. Moreover, this paper provides the complete E-Glass electronic circuit in which the electronic scanning system to tackle the objects and time signals are included. This E-Glass could be used by the blind to assist them in their ways without any human assistance. Moreover, it will be used by the blind to make them self confidence, to let them walk independently and to increase their morality. It is important to note that the hardware and software components of the E-Glass are not expensive. This work could be provided to the practitioner's people in the industry or to the students of the department of electrical or biomedical engineering. [Journal of American Science 2010;6(4):34-42] (ISSN: 1545-1003).

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1. Introduction

Currently, there are an estimated of 45 million blind people and 135 million visually impaired people worldwide [World Health Organization 2001]. Unfortunately, 90% of people who are blind live in developing countries this represents around 33.3 million [World Health Organization 2001]. Moreover, in developing countries, it is believed that 60-80% of children who become blind die within 1-2 years [Lewallen, S et al, 2001].

Furthermore, more than half of the world's blind live in India (9 million), Africa (7 million) China (6 million) and Arab region (7 million). If trends continue 75 million people will be blind by 2020 worldwide.

The idea of this research is to build a first generation of an electronic glass (E-Glass) for the blind. This could open the avenues for the researchers in the electrical, biomedical and computer engineering departments to improve this kind of research based on some foundations provided in this paper.

This work will eventually be the first step to use the technology as external functionality to help the blind persons to indemnify the missing part.

This paper is organized as follows: section 2 presents an overview of the related work. Section 3 presents the research methodology. Section 4 presents the theoretical part. Section 5 presents the practical part. Conclusions and future work are presented in section 6.

2. An overview of the related work

To date, there are no similar research studies related to this topic. However, there are few references that may be used to build the proposed E-Glass such as engineering and information technology field.

Based on the literature [DuBose TJ, Baker AL 2009] and [Doppler Ultrasound History 2008] the

Ultrasound signals are a Real Time Locating System (RTLS) or Indoor Positioning System (IPS) technology used to automatically track and identify the location of objects in real time using simple, inexpensive nodes (badges/tags) attached to or embedded in objects and devices, which then transmit an ultrasound signal to communicate their location to microphone sensors.

2.1 Ultrasonic wave and echo

A sound wave is typically produced by a piezoelectric transducer encased in a probe [*disambiguation needed*] [Ang Jr., ES; Gluncic V, Duque A et al. 2006]. Strong, short electrical pulses from the ultrasound machine make the transducer ring at the desired frequency. The frequencies can be anywhere between 2 and 18 MHz The sound is focused either by the shape of the transducer, a lens in front of the transducer, or a complex set of control pulses from the ultrasound scanner machine (Beam forming) [Bricker L, Garcia J, Henderson J, et al. 2000]. This focusing produces an arc-shaped sound wave from the face of the transducer. The wave travels into the body and comes into focus at a desired depth.

Older technology transducers focus their beam with physical lenses. Newer technology transducers use phased array techniques to enable the sonographic machine to change the direction and depth of focus. Almost all piezoelectric transducers are made of ceramic [Bricker L, Garcia J, Henderson J, et al. 2000].

Materials on the face of the transducer enable the sound to be transmitted efficiently into the body (usually seeming to be a rubbery coating, a form of impedance matching). In addition, a water-based gel is placed between the patient's skin and the probe.

The sound wave is partially reflected from the layers between different tissues. Specifically, sound is reflected anywhere there are density changes in the body: e.g. blood cells in blood plasma, small structures in organs, etc. Some of the reflections return to the transducer [Edler I, Hertz CH. 2004].

The return of the sound wave to the transducer results in the same process that it took to send the sound wave, except in reverse. The return sound wave vibrates the transducer; the transducer turns the vibrations into electrical pulses that travel to the ultrasonic scanner where they are processed and transformed into a digital image [Donald I, Mac Vicar J, Brown TG, 1995].

2.2 Forming the image

The sonographic scanner must determine three things from each received echo [The History of Ultrasound 2006]:

- How long took the echo to be received when the sound was transmitted.
- The focal length stored in the phased array is deduced enabling a sharp image of that echo at that depth (this is not possible while producing a sound wave).
- How strong the echo was. It could be noted that sound wave is not a click, but a pulse with a specific carrier frequency. Moving objects change this frequency on reflection, so that it is only a matter of electronics to have simultaneous Doppler sonography.

2.3 Displaying the image

Images from the sonographic scanner can be displayed, captured, and broadcast through a computer using a frame grabber to capture and digitize the analog video signal. The captured signal can then be post-processed on the computer itself [Woo, Joseph 2002].

2.4 Studies on the safety of ultrasound

A study at the Yale School of Medicine found a correlation between prolonged and frequent use of ultrasound and abnormal neuronal migration in mice. A meta-analysis of several ultrasonography studies found no statistically significant harmful effects from ultrasonography, but mentioned that there was a lack of data on long-term substantive outcomes such as neurodevelopment [Merritt, CR 1989].

2.5 Voice biometric

Voice biometric consists of two major tasks, that is, Feature Extraction and Pattern Recognition. Feature extraction attempts to discover characteristics of the sound signal, while pattern recognition refers to the matching of features in such a way as to determine, within probabilistic limits, whether two sets of features are located from the same or different domain [Rabiner and Juang, 1993].

In general, voice biometric can be subdivided into voice identification, and voice verification. Voice identification will be used in this paper to send the sound to blind person who used this system.

2.6 Digital Signal Processing (DSP)

The Digital Signal Processing (DSP) is the study of signals in a digital representation and the processing methods of these signals [Kuo and Gan, 2004].

The DSP and analogue signal processing are subfields of signal processing. Furthermore, the DSP includes subfields such as audio signal processing, control engineering, digital image processing, and speech processing. RADAR Signal processing, and communications signal processing are two other important subfields of DSP [Lyons, 1996].

3. Research Methodology

In this paper, first we have build two electronic circuits integrated with each other, see figure 4 the first circuit generating ultra sonic signals that send/receive signals to get and analyse the information about the objects from the environment like a radar system.

The second circuit received the processed ultra sonic signals into voice biometric chip to send different types of alarming voice to help the blind person to avoid any obstacles in his/her way.

4. Theoretical Part

This section provides the procedure for producing the proposed and the future view for this E-Glass. By forming and displaying the image.

4.1 E-Glass system parameters and constraint

The first circuit generating ultra sonic signals that send/receive signals to get and analyse the information about the objects from the environment like a radar system. This part could be extended to form and display the objects-image by using the following steps:

- In E-Glass application the source of ultrasound is the transducer.
- A typical disc transducer produces a field roughly in the form of a beam, as you see in figure-1 [Valma J Robertson, Kerry G Baker 2001].

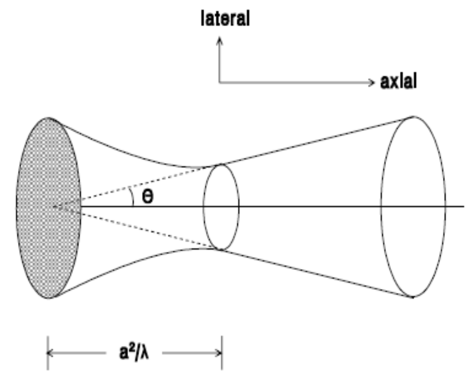

Figure1: Beam Behaviour.

- The analysis is simplified for operation at a single frequency, and this will be assumed. For distances less than a2/λ, where a is the transducer radius, and λ the wave length, the beam contracts to a radius of about a/2. This region is referred to as the near field.
- The transducer is characterized by its total power output, corresponding to the integral of the time-averaged intensity over the face of the transducer. Formally this can be written as follow:

$$W=\frac{1}{T}\int_{t=0}^{t=T}\int_{S} i(\mathbf{r},t)\, d^2\mathbf{r}dt \qquad (1)$$

Where T is the period and S is the face of the transducer. The quantity I, where A is the effective area of T 'W/A the transducer is the time-averaged intensity, spatially averaged over the face of the transducer. The boundary of the transducer face is determined by intensity drop off and hence is not exactly equal to the geometrical intensity.

- The boundary is taken where the intensity has dropped to 25% of the maximum transmitting ultra sonic waves. The quantity *ISATA* (*z*) is similarly defined as the spatial and temporal average over the effective beam area at distance z from the face of the transducer.

- Beyond this point the intensity quickly approaches an inverse dependence on axial distance. *ISPPA* is the spatial peak pulse average in

$$I_{SPPA}=\frac{1}{T}\int i(a^2/\lambda,t)dt \qquad (2)$$

For a pulsed system, the quantity T is the repetition period. In this case, as mentioned previously, the variation is less extreme, since it is the superposition of curves for each spectral component and the positions of the extreme are frequency dependent.

4. 2 E-Glass and dimensional sonic wave

The ultra sonic wave used in this paper based on one dimensional sonic wave, to the future use, can improve the electronic circuit in figure 5, to work with two or three or fourth dimensional waves [Gale Encyclopedia of Medicine 2001]. For one dimensional wave, one can fellow these steps:

- Sonic disturbance [Valma J Robertson, Kerry G Baker 2001] is propagated by the motion of the particles of the propagating medium vibrating around their equilibrium positions. The motion may be described by Newtonian mechanics. For mathematical simplicity consider a fictitious medium in which motion is restricted to one dimension. If $u(x)$ is the particle displacement from equilibrium at x then the force on a volume element about y is given by:

$$dF=(\rho dxdydz)\cdot\frac{\partial^2 u}{\partial t^2} \qquad (3)$$

Where: ρ is the density of the medium. The net force in the x direction is the difference between the forces at $x+dx$ and x operating on the area $dydz$.

- If the stress σ is defined as the force per unit area then

$$dF=[\sigma(x+dx)-\sigma(x)]dydz=\frac{\partial\sigma}{\partial x}\cdot dxdydz \qquad (4)$$

- This leads to the continuum equation:

$$\frac{\partial\sigma}{\partial x}=\rho\frac{\partial^2 u}{\partial t^2} \qquad (5)$$

- Since the displacement depends upon position the system becomes distorted. An element originally of length dx extending from x to $x+dx$ will now extend from $x+u(x)$ to $x+dx+u(x+dx)$ resulting in an increase in length of the element of $u(x+dx)-u(x)$. The dimensionless quantity strain is defined as the fractional distortion and hence is given by:

$$\varepsilon(x)=\frac{u(x+dx)-u(x)}{dx}=\frac{\partial u}{\partial x} \qquad (6)$$

- After steps in sections 4.1 and 4.2, one can build matrix of signal through the reflected sonic wave signals or (echo) and then forming displaying the image for the entire object, this part are not described in this paper, which is considered as a future view for the upcoming E-Glass research.
- Based on sections 4.1 and 4.2 in this paper, the E-Glass behaviour waves are described and the constraints defined the waves dimensional then the output of the first circuit will be used as input to the second circuit or (voice circuit).

4.3 Forming and displaying image in E-Glass

This part is still under investigation, this section will be discussed in the next generation of this E-Glass.

4.4 Neuron node connection for E-Glass

Neuron node connection is a mediator part between the embedded E-Glass system and the human optical nerves, the idea is to capture the sending human optical nerve into E-Glass system and through the artificial neuron node, there will be testing for sending and receiving a sonic wave's data between the embedded system and the human nerve.

This part is still under investigation, this section will be discussed in the next generation of this E-Glass.

5. Practical Part

This section covers what we achieved from E-Glass project, this section includes some preliminary results that may improve the second E-Glass generation.

5.1 The proposed E-Glass system

The proposed E-Glass works through an electronic circuit to scan and to collect information about the entire objects using ultrasonic signals (echo system) such as the one used for a radar system. This electronic circuit could be developed to be used by the blind.

The E-glass system for the blind could be built utilizing the communication passive signal theory between the environment and the blind persons see (Gonzalez et al 2002). The passive signal sends and receives data to and from the objects (Guo and Liddell, 2002). The signals will analyse these objects based on the length of the collected signals per a time using a quantization sampling signal (G. Fant 1970).

The analyzed data can then be used by the voice circuit by comparing this collected data with the predefined conditions on the voice circuit or system threshold (B. Gold and N. Morgan 2000). This will allow taking decisions by the proposed system to give different types of alarms.

5.2 General View of the E-Glass

The E-Glass research is to build a discipline view between the engineering and medical fields and utilizes this discipline to help blind persons.

This E-Glass system is composed of software based on the artificial intelligence programming capabilities and hardware components to install these programs.

The software use VHDL (verlog hardware description language) programming to define the functionality of the re-programmable microcontroller; this is considered as the brain of the E-Glass system.

The hardware is composed of two electronic circuits systems. The first electronic circuit is composed of two radars build on a PCP card see figure 2 and the second electronic circuit is composed of a wire or a wireless voice chip.

5.3 How the E-Glass Works?

This E-Glass receives the information from the two radars systems that are embedded into the E-Glass. This information will be analyzed in the artificial intelligence software and will produce a warning about any obstacle objects through a voice system.

This E-Glass works through the ultra sonic waves by sending radar signals for a distance from 2 meters to 50 meters and 120 degrees as a vertical and horizontal cover angle along with 60 degrees to cover the right and left, as a result, in total the cover angle will be 270 degrees. See figure 2. One of the characteristics of this E-Glass is that it can identify any small object with a 2 cm^2 area or more from 2 meters distance.

This E-Glass will work through the following two phases:

5.3.1 First phase

The first radar will be put on the left part of the E-Glass.

This radar will send signals to the left part and will receive signals from the left part. Then, this radar will analyse all the data which are collected, to cover the left part. The second radar will be put on the right part of the E-Glass. It will send signals to the right parts and analyse all the data which are collected from the radar, to cover the right part see-figure 1.

Therefore, after receiving the information from the two radars, it will be analyzed in the artificial intelligence software. This analysis could be done through the first electronic circuit programs that are connected to the two radars.

5.3.2 Second phase:

The second electronic circuit program will analyze the signals that will be received from the electronic warning and alarming device (voice system).

This second electronic signal contains the predefined data (these data is considered as a system specifications) to give a scaled warning to the blind persons. This will be based on the dangerous degree of the situation facing the blind persons using the analysis constraints for timing diagram system.

5.4 The proposed E-Glass Components

The proposed E-Glass system is composed of the following components micro controller, memory, electrical circuits, timing system and a voice chip.

The first generation of this embedded E-Glass system prototype was built in Jordan see-figure 1.

This prototype model was build on the bases of the electronic circuit in figure 4, which actually includes two integrated circuits; the first circuit is in the above part of figure 4; it will collect information about objects or obstacles from the real environment, While the second circuit is in the bottom part of figure 4; it will analyse the collected information to take decision and to give a scaled warning voice to blind persons based on the system condition.

5.4.1 First Generation of the E-Glass Prototyping

Figure 1 presents the first generation of the E-Glass embedded system, this prototype could be built in engineering laboratories based on the electronic circuit listed in figure 4.

5.4.2 The Electronic Scanning System to Tackle the Objects

Figure 2 describes the scanning system embedded into the E-Glass through the electronic circuit on figure 4.

The scanning system sends signal to tackle the objects vertically and horizontally.

Assuming that the E-glass system is fixed on the middle area of the human body; the vertical signals covers from 0 degree to 180 degree range; while the horizontal signals, covers from 90 to 270 degree range as seen in figure 2.

Figure 2: The E-Glass Embedded System.

5.4.3 Sending and Receiving Signals Timing System.

The E-Glass system will send signal to capture the environmental object each 100 ms and receive signals each 10 ms. The timing system diagram in figure 3 works as follows:

The embedded timing module generates ultra sonic signals based on 8 bits cycle for each pulse.
The embedded timing system for the E-Glass receives input signals from the environmental objects each 10 ms.

The embedded timing system for the E-Glass sends input signals from the system to the environment each 100 ms see-figure4.

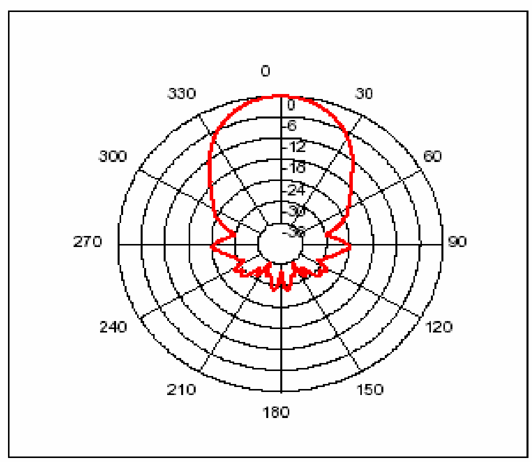

Figure 3: The Electronic Scanning System to Tackle the Objects

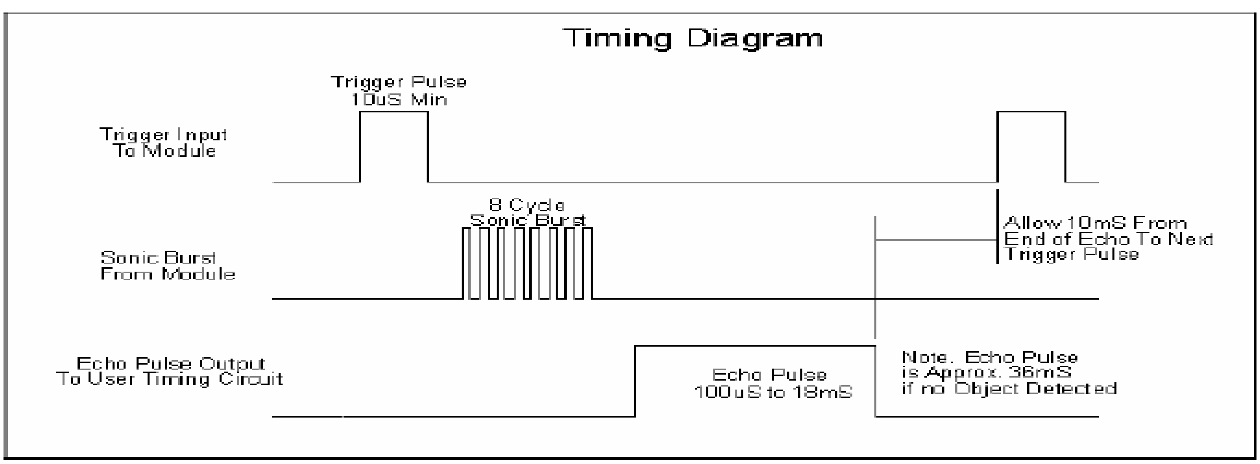

Figure 4: Sending and Receiving Signals Timing System

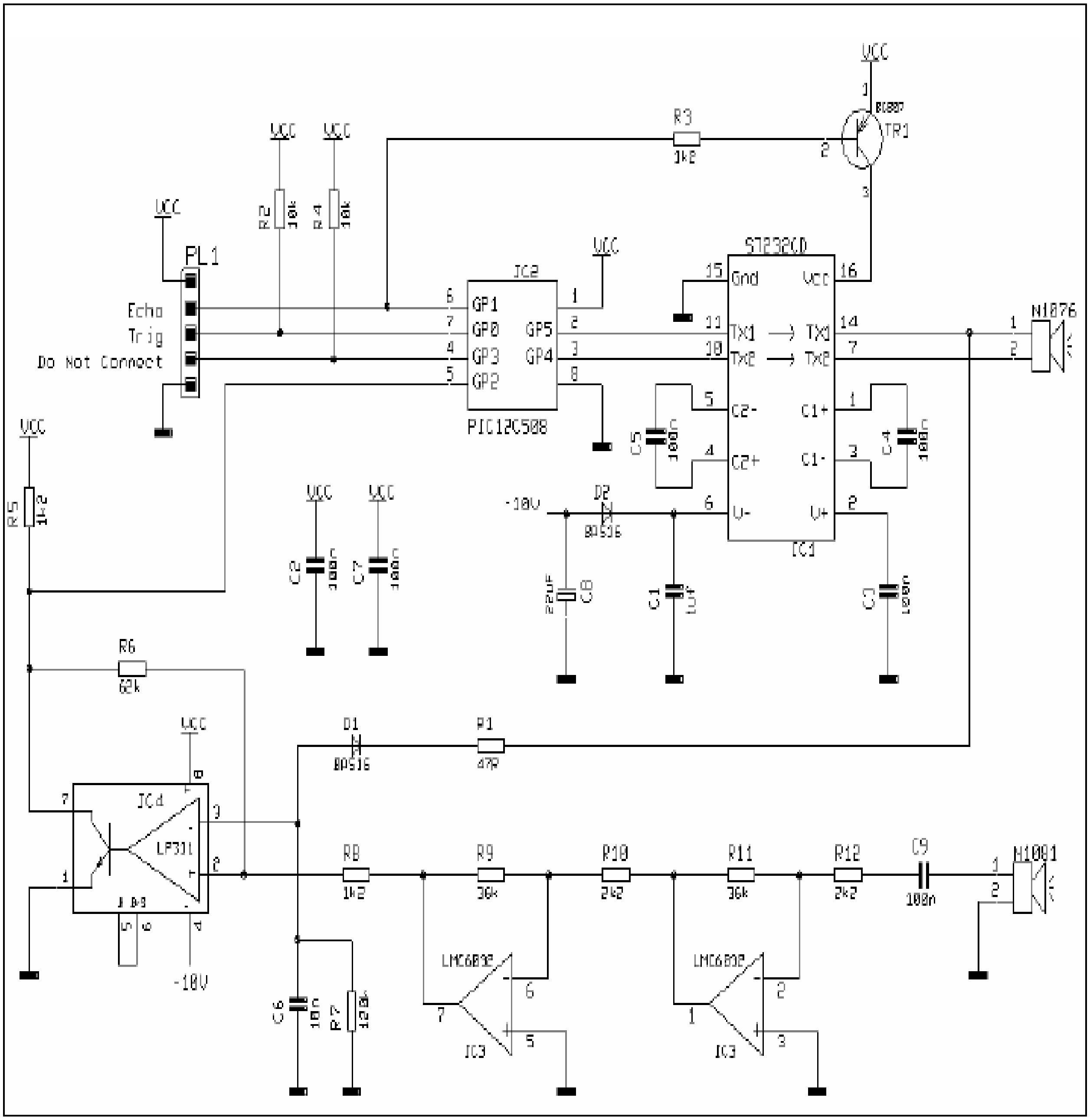

Figure 5: The Completed E-Glass Electronic Circuit for the first generation.

6. Conclusion and Future work

The research in the field of using information technology IT to be part of a human functionality to assist them in their daily life is not developed yet.

The work presented in this paper is innovative from the social view. As one note that there is no similar work undertaken to date. Therefore, this research opens avenues to a new research field to fulfil special needs people.

As a future work, this kind of research should be explored through the medical engineering fields in order to improve it. For instance, the future view of this E-Glass system is to build it as a replaceable part of the damaged human neural system. This will be used as an internal part of a human body utilizing the ultra sonic capabilities especially the one used in medical and pattern recognition. This system will directly replace the human optical nerves instead of the damaged eyes.

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