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作品名稱　**Method of prosthetic vision**

得獎獎項

國　　家　**Ukraine**

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作者照片

ABSTRACT

This work is devoted to solving the problem of orientation in the space of visually impaired people. Working on the project, a new way of transmitting visual information through an acoustic channel was invented. In addition, was developed the device, which uses distance sensors to analyze the situation around a user. Thanks to the invented algorithm of transformation of the information about the position of the obstacle into the sound of a certain tone and intensity, this device allows the user to transmit subject-spatial information in real time. Currently, the device should use a facette locator made of 36 ultrasonic locators grouped in 12 sectors by the azimuth and 3 spatial cones by the angle. Data obtained in such a way is converted into its own note according to the following pattern : the angle of the place corresponds to octave, the azimuth corresponds to the note and the distance corresponds to the volume. The choice of the notes is not unambiguous. However, we used them for the reason that over the centuries, notes have had a felicitous way of layout on the frequency range and on the logarithmic scale. Therefore, the appearance of a new note in the total signal will not be muffled by a combination of other notes. Consequently, a blind person, moving around the room with the help of the tone and volume of the sound signals, will be able to assess the presence and location of all dangerous obstacles. After theoretical substantiation of the hypothesis and analysis of the available information, we started the production of prototypes of the devices that would implement the idea of transmitting information via the acoustic channel.

INTRODUCTION

Despite all attempts to make the lives of the blind and visually impaired easier, the environment remains hostile and dangerous for them. Moving around the house on a daily basis can cause injuries, not to mention moving on an unfamiliar street. This problem not only complicates life, but also does not allow normal socialization and self-realization. [1]

The problem facing researchers and inventors is the large flow of information that must be simultaneously transmitted to the brain. [2]

Even if we simply consider the number of nerve fibers that go from the eyes to the brain [3], we can say that its prosthetics is impossible. The only channel that can be at least partially equal to the visual is the acoustic. [4] The most classic example is a sighted person, who simply tells a blind one what happens around. As a matter of fact, throughout history it was the only way to inform visually impaired people. That is why it was decided to conduct research into some methods of transmitting information using sound vibrations in various forms. During the study, it became clear that the verbal form of data transmission is imperfect due to the long processing of words by the brain and the inability to transmit multiple signals simultaneously, which significantly affects the response time of the user. In the research , response time was given a high priority. In dangerous situations that may occur when a visually impaired person moves, for instance, on the streets, a long reaction to an obstacle in the form of a fast moving object, such as a cyclist or car, can cause injuries and harm to the disabled user .

Therefore, it was decided to analyze the work of the ear itself, as the primary receiver of acoustic information (Pic. 2). The sound, getting into the human ear, eventually enters a long cone-like part of the ear, twisted into a spiral. [5] There are specific receptors along the walls of the cone, each of them have their own resonant frequency and the quality factor caused by the actual diameter of the cone at a given location and the shape of the receptor. Consequently, any sound signal is automatically divided into smaller pulse groups from resonators of a specific frequency in the ear . Therefore, it was decided to encode the signals with monotonic sound oscillations.

After the research, a prototype device was developed that scans the space and converts the information into appropriate audio signals. With the further development of this idea and the beginning of mass production of such devices, visually impaired people will be able to move around much easier and more efficiently. This will not only improve their standard of living, but also allow such people to achieve self-actualization. Also, the absence of analogues of such a device makes it easy to recoup the money invested in the development of the idea and the continuation of further research and development of these devices.

THE GOAL OF THE PROJECT

The aim of the project is to give blind people the ability to have their spatial orientation and assist them to move safely in surroundings with moving obstacles.

The task of the project is to think up the method of transmitting information about the position of the obstacles around the user and to realise this method in a reliable device with a user-friendly and intuitive interface.

The object of the research is the specifics of the information transmission into the human's brain from the receptors. This study seeks to search for the optimal method to transmit the maximum amount of additional information through these receptors.

The subject of the research is the invented device, which allows the process of information transmission about the obstacles in the user's surrounding using his hearing without overloading it.

Although relatively little results are received due to the complexity of the problem, the relevance of the project is approved by an impressive amount of work which is done in this sphere.

The novelty of the project is that the invented device is the first one to try to use the acoustic channel to transmit signals about surroundings not by means of words. Because the usage of words requires large resources of the brain, when tones are processed in a much faster and easier way it engages less brain resources. As a result,the invented device can use hearing to transmit large amounts of information.

Regrettably, we cannot regain eyesight, because the acoustic channel's capacity is several times smaller than the capacity of eyes' channels. [2] [3] [4] [5] Hopefully, we can inform users about the appearance of the obstacles in real time via such devices, hence, it becomes convenient enough to move around safely.

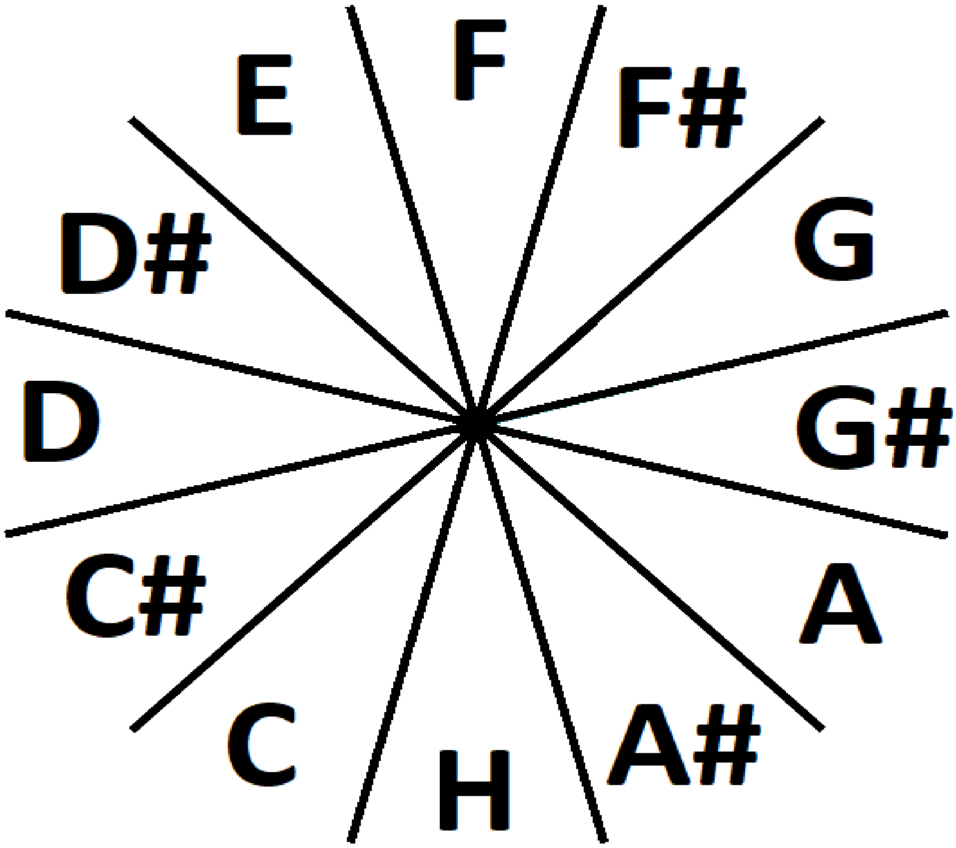
As we found out during the research such technologies could also be useful for firefighters, who work in smoky places.

METHOD OF SURROUNDING PROCESSING

The amount of information which is transmitted from eyes to the brain is so colossal that finding or creating another channel of transmission with such capacity is impossible. Therefore, we simultaneously use the acoustic channel operating the information about the surrounding and obstacles around. In general, it is enough just to know the position of the objects around a person to have the ability to move safely. That is why the device does not transmit the information about the colour, and texture of the object.

To gather this information the surrounding area was divided into 12 sectors. It is enough to understand where the obstacles are. On top of that, it is easy to match each sector with a unique note. Such matching makes the usage of this method intuitive and easy to adapt.

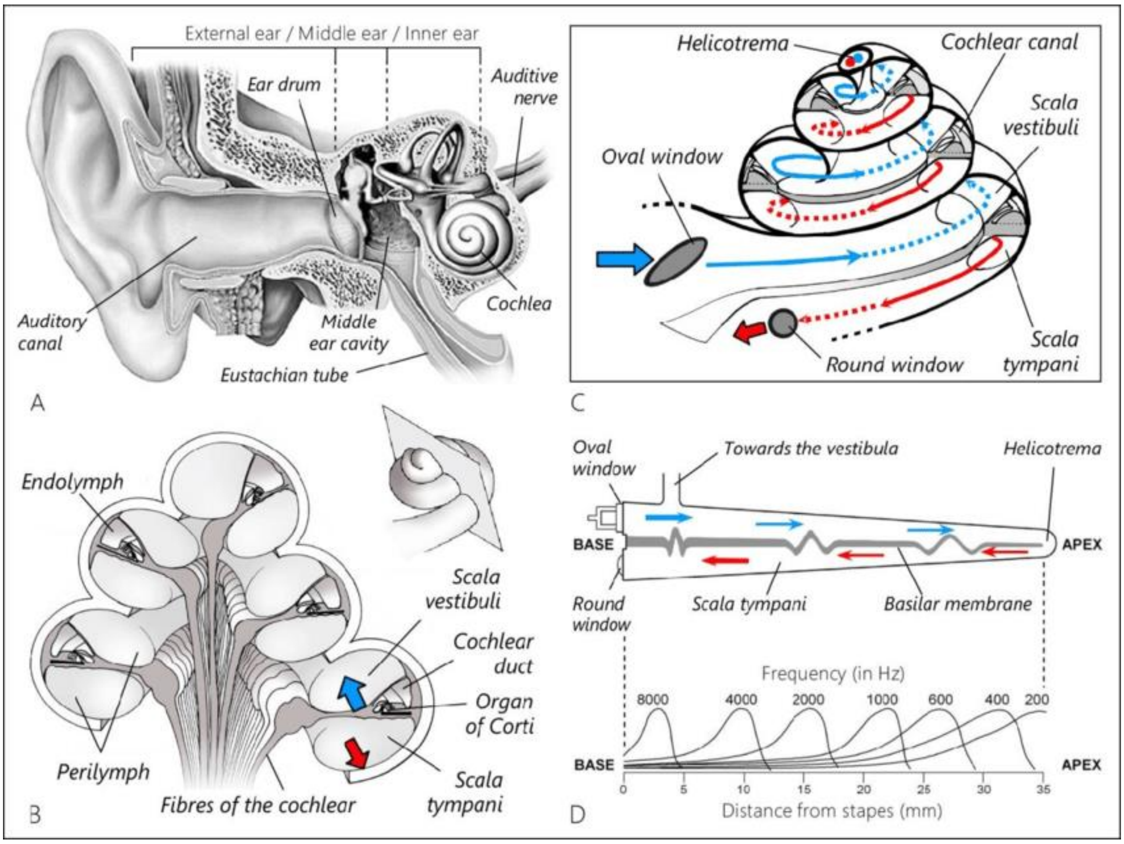
Direction	Tone
Front	F
Front - left	F#
Left - front	G
Left	G#
Left - behind	A
Behind - left	A#
Behind	H
Behind - right	C
Right - behind	C#
Right	D
Right - front	D#
Front - right	E



Pic.1 Scheme of matching of sensors to notes of one octave

SPECIFICS OF TRANSMISSION OF INFORMATION THROUGH THE ACOUSTIC CHANNEL

` Information in the form of sound may be transmitted in several ways.[6] The most common is by means of words but it has some serious disadvantages. For this reason, I have found out another method to transmit information. To compare these methods several parameters were used such as the ability to transmit several signals at the same moment of time, the speed of signal transmission, the speed of signal perception and the ability to adapt to the usage of the system.

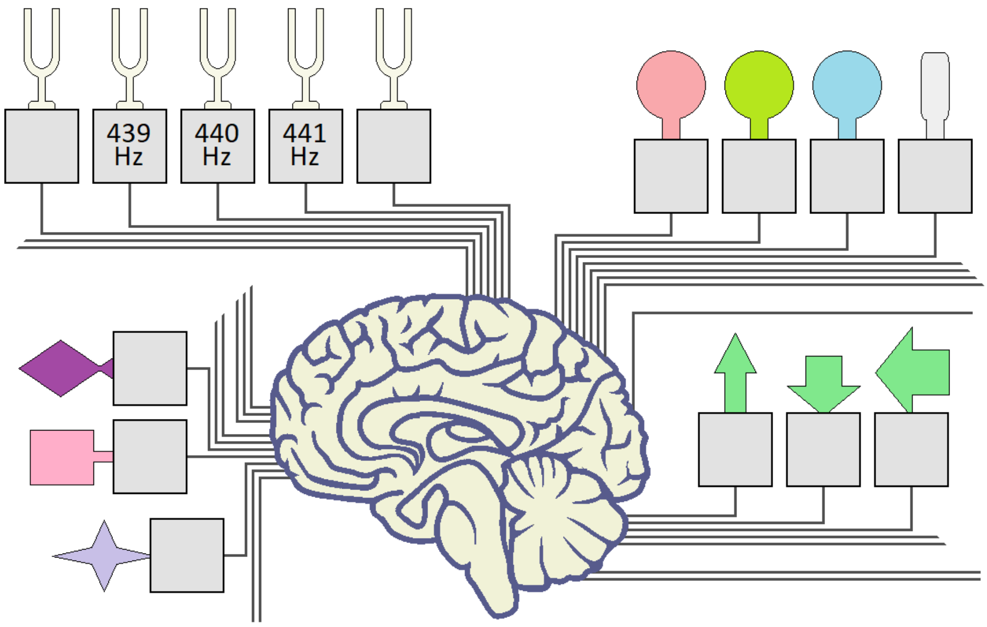


Pic.2 Structure of human's ear

(c) https://www.researchgate.net/figure/A-Longitudinal-section-of-the-human-auditory-organ-B-diagram-of-a-section-through-the_fig2_286446501

The main drawback of the word usage is the fact that when several words sound at the same time, their recognition becomes impossible.[7] This would negatively affect the speed of signal transmission. Instead, the notes are devoid of this disadvantage. Human's ear can recognise up to 6 different notes at the same time. Also, when notes are grouped, for instance, in octaves, the number of recognised notes is increasing.

Considering the required length of the signal to transmit a certain signal, the verbal form also is much worse. Because the average time needed to pronounce one word is about a second, the phrase: "Obstacle is on the right" takes as much as two or even three seconds. However, it takes less than the hundredth part of a second to percept a note.

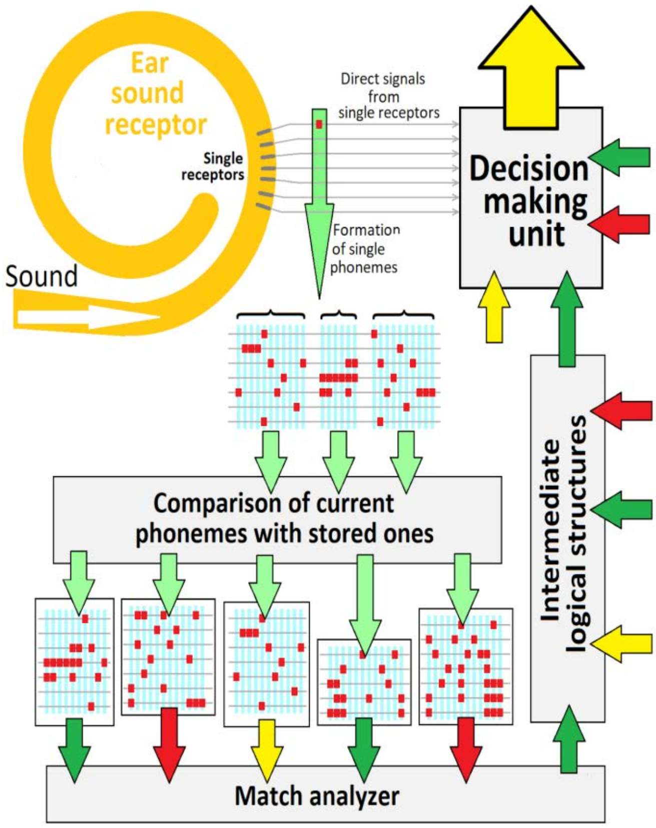


Pic.3 Simplified scheme of getting information about the outside world by the human brain

To analyze the time required for the perception of signals in the form of words and notes, it is necessary to consider the mechanism of perception of acoustic information by the brain. (Pic.3) In essence, we have a group of nerve fibers, ending in a resonator. It generates an electrochemical pulse in the nerve fiber provided that it is affected by the fluctuations of a certain frequency. Therefore, each resonator easily and almost instantly catches the tone of the sound oscillation. Thus, when several resonators periodically catch their own resonant oscillations over time, analysing such information our brain concludes that a certain letter or even a word sounded. [6]

To analyze the time spent on perception of information in the form of words and notes, it is necessary to consider the perception of acoustic information by the brain. When the word sounds the length of the signal is several times longer. It significantly affects processing time. Also, to understand the meaning of the word it is divided into phonemes, which are later compared with existing ones and, after all, formed into logical structures.

This process is not as long as the sound of words but it also needs to be taken into account. Instead, the notes are processed almost directly, because they consist of a short phoneme. Due to this fact, the reaction to signals consisting of notes is many times faster.



Pic.4 Simplified scheme of the brain’s analysis of acoustic information

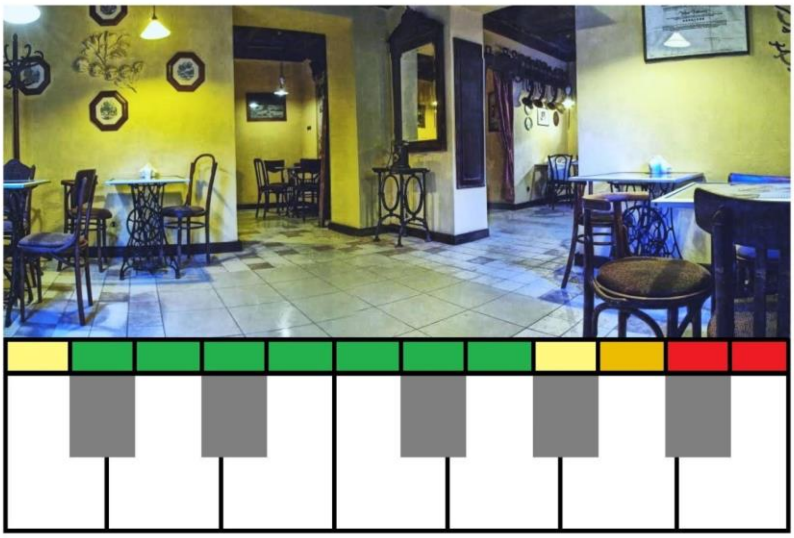
The only advantage of the verbal form is the relative ease of adaptation to it. But if you look into the processes of perception of notes, the situation ceases to be so unambiguous. Because after an adaptation process to the note signal, the brain develops reflexes that correspond to each note. This makes it even better and easier to respond to the new objects in the environment.

Another important advantage of notes is that they do not reload the acoustic channel and allow the user to continue to perceive sounds from the environment.

ALGORITHM OF WORK OF THE PROTOTYPE

The prototype uses a facet locator to process information about the environment. The space around the user is divided into sectors by azimuth and parts of these sectors in the direction relative to the horizon: horizontally-straight, up and down.

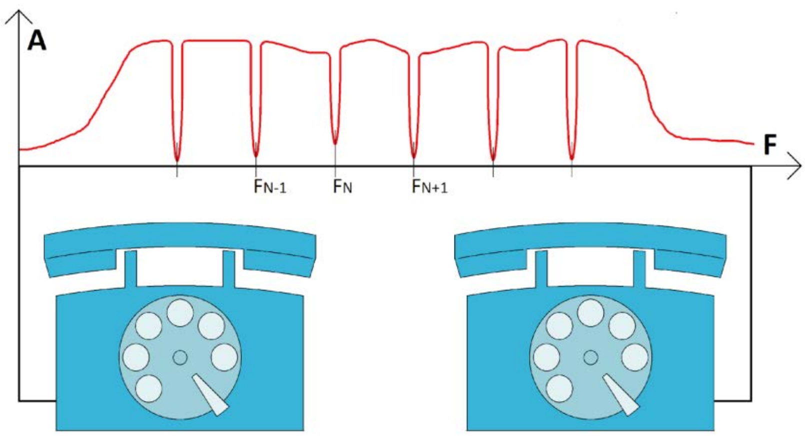
In such a way, using 36 locators, 3 per sector, directed in three directions, we obtain information about the entire space (Pic.1). To initialize the zones, each direction is matched to its own octave, the azimuth to a note. The device uses the volume of the corresponding note to indicate the distance to the subject.



Pic.5 One of the options for assigning different directions to certain notes, where green is zero volume and red is maximum volume

This system makes it easy to distinguish between different types of obstacles. For instance, when a column appears in front of the user, one note of different octaves is heard. When a horizontal obstacle appears, such as a tree branch, several notes of one octave will be heard. They will correspond to the height of the branch; As you approach a table, several notes of different octaves will sound (Pic.5)

Naturally, the question arises whether the additional usage of the ear will not deprive it of the ability to perform its primary function. Studies [7], [8] show that our language has a huge information redundancy and noise immunity. And even when at telephone communication by means of narrow-band notch filters [8] from human language to cut out some frequencies (Pic.6) legibility of language practically will not suffer. Therefore, we can safely use several audio frequencies to transmit the information about the spatial situation.

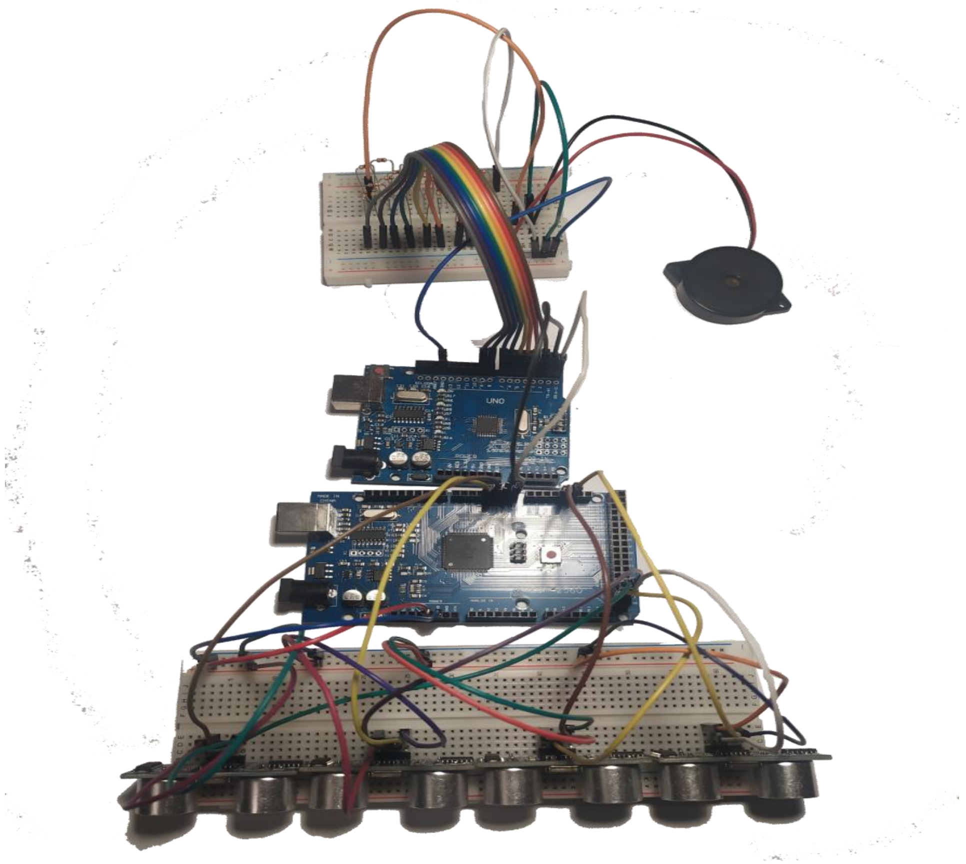


Pic.6 Scheme of a telephone communication line with several "cutouts" in the frequency spectrum of reception-transmission

It is worth pointing out that if a user enters narrow spaces, such as crowds of people or narrow corridors, the number of notes will increase. This may affect the user's ability to distinguish signals. Therefore, in such situations, the microcontroller will specifically reject the sound of notes that correspond to distant objects, leaving only near ones.

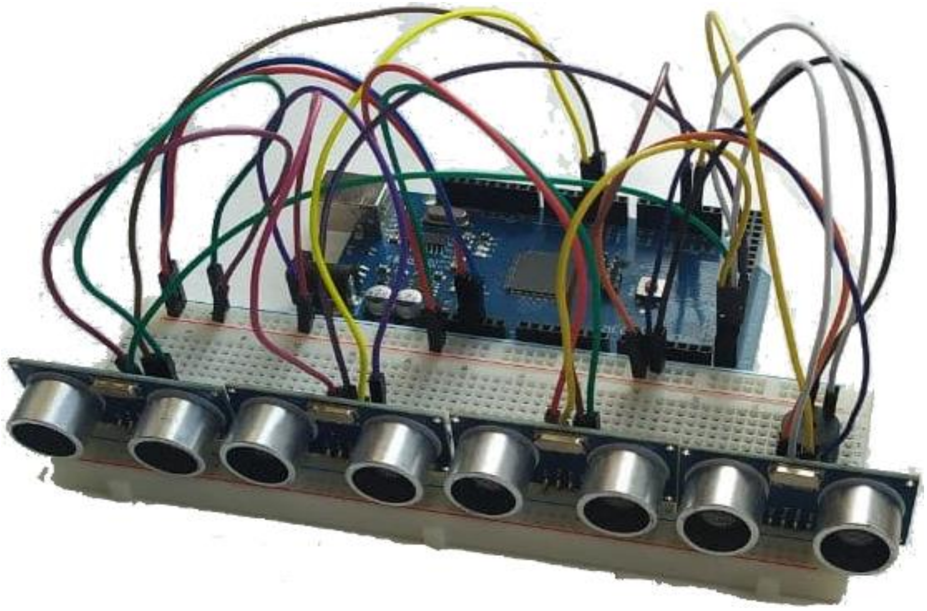
PROTOTYPES OF DEVICES BASED ON INVENTED ALGORITHM

During the research two prototypes were invented. Both of them use ultrasonic sensors to gather information and play sound according to the position of the obstacles in front of them.



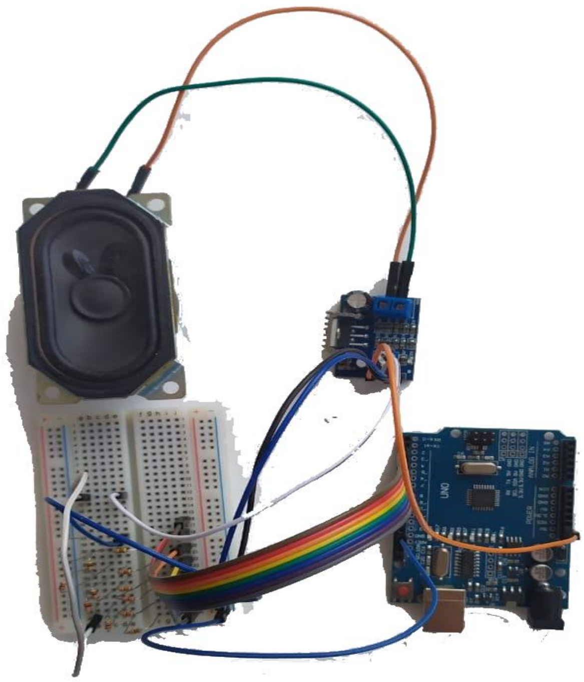
Pic.7 First version of the prototype

The first prototype used two Arduino microcontrollers. [8] One to gather and convert data into volume values. When there are too many notes played at the same moment of time, it rejects signals about distant obstacles.



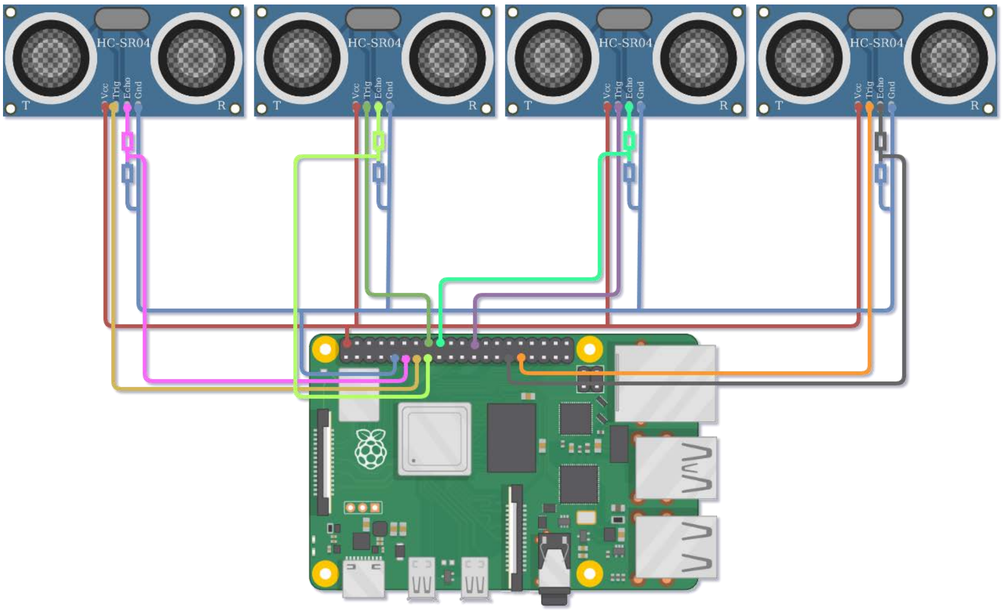
Pic.8 Microcontroller “Arduino Mega” which gathers and processes information

Another microcontroller is used as an audio card. It has a pre-entered database with sine wave values at a time. By selecting the appropriate values and summing them, the volume of each note is taken into account. This microcontroller finds the value of the sound wave at a given time. This value is transmitted to the speaker, followed by a sound heard by the user.



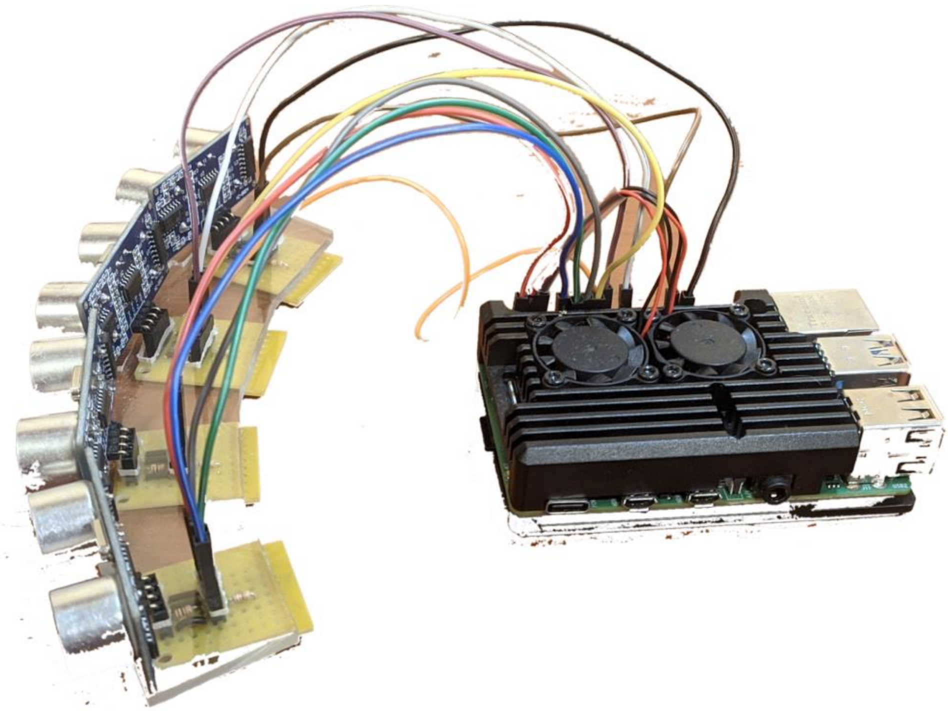
Pic.9 Microcontroller “Arduino Uno” which acts as audio card with digital to analog converter and amplifier of low-frequency oscillations

The second prototype was built on the platform of Raspberry Pi. [9] As it has greater abilities it uses the same board to process and play sound.



Pic.10 Scheme of connection of ultrasonic sensors on second prototype

Usage of Raspberry Pi made the project much smaller due to the absence of two boards, digital to analog converter and amplifier of low-frequency oscillations.



Pic.11 Second prototype based on platform of “Raspberry Pi 4B+”

CONCLUSION

During the research it was found the method of transmitting information about the position of obstacles around the user. After comparing possible ways of transmission of sound signals it became obvious that the sound of notes is the best means of information for visually impaired people due to high speed of perception, great capacity of signal and ability to develop reflex reactions.

The construction of two prototypes of the device made it possible to use that theoretical information. In future, the development of this device will allow users with sight disabilities to move much more safely and easily. Also, the conversion to Raspberry Pi platform made it possible to use cameras instead of ultrasonic sensors and run artificial intelligence on board of devices.

Consequently, after the beginning of mass production of the following devices, firstly, the visually impaired people will be able to improve their standard of living. Secondly, the investment in this device will be recouped in a short time.

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This project is very useful for blind people as the authors try to use sound of different pitches and length to orient the blind people. The authors have built an embedded system for this application. But, how well this system can benefit blind people is not presented in this work. That is, there are no experimental results in this report.