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DEVELOPMENT OF IOT STETHOSCOPE WHICH SUPPORTS THE TELEMEDICINE PROCESS

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ABSTRACT

Modern stethoscopes can be divided to three main categories: acoustic, electronic, and stethoscopes for hearing impaired. The acoustic stethoscopes can be divided into several classes depending on their purpose. For hearing impaired medical professionals, special adaptors called stethomate tips, allows medical professionals who wear hearing aids to use the stethoscope with their hearing aids. Other electronic stethoscopes, like Thinklabs one digital stethoscope, have headphone jack which allow hearing impaired professionals to use a comfortable headphone with the stethoscope
However, stethoscopes intended for remote diagnosis of patients have not existed until the beginning of this research. The purpose of the IoT stethoscope is to upgrade the telemedicine process by enabling the patient to plug the stethoscope into his device and let the doctor remotely listen to his body's internal sounds.
The steps to construct of the IoT stethoscope have been described and the detailed levels of the components and the technology options that can be used on each layer is presented. The technologies that can be used on each layer of the developed stethoscope have been researched.
Based on the technology researches the developed IoT stethoscope has been implemented and realized. The implemented device demonstrated perfect results in the preliminary tests.
The implemented stethoscope can be used in providing online medical care to patients who leave in villages where no doctors are available, hikers in emergency situations, and patients during epidemic situations.

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Introduction. The stethoscope is the most recognizable medical device to all of us, used to hear internal sounds of human body such as lungs, heart, and abdomen, as well as determine blood pleasure. Stethoscope helps in detection and diagnosis of many disorders such as pneumothorax, pneumonia, congestive heart failure, acute asthma, chronic bronchitis and emphysema, etc. [1]

Modern stethoscopes can be divided to three main categories: acoustic, electronic, and stethoscopes for hearing impaired. The acoustic stethoscopes can be divided into several classes depending on their purpose. The electronic stethoscopes converts physical vibrations of the sound into an electronic signal and optimize them for improved listening and diagnosis [2-3].

For hearing impaired medical professionals, there are several options available. Special adaptors called stethomate tips, allows medical professionals who wear hearing aids to use the stethoscope with their hearing aids.

Other electronic stethoscopes, like Thinklabs one digital stethoscope, have headphone jack which allow hearing impaired professionals to use a comfortable headphone with the stethoscope.

Depending on the brand of the hearing aids and digital stethoscope, transmitters that wirelessly sends the stethoscope sound to the hearing aids can exist [3-4].

However, stethoscopes intended for remote diagnosis of patients have not existed until the beginning of this research.

In many places in the world, such as villages far from cities in developing countries, medical centers do not have doctors who work there. They provide health services by connecting to doctors who live in the cities using telecommunication technologies. During online sessions, video call is maximum what a doctor can have with the patient which is so little to put accurate diagnosis and assign the best treatment plan to the patient because the lack of helping medical instruments. A stethoscope which allows to remotely listen to the patient body's internal sounds will make a big difference, implementation of which is the aim of this paper.

Development of the IoT stethoscope. The purpose of the IoT stethoscope is to upgrade the telemedicine process by enabling the patient to plug the stethoscope into his device and let the doctor remotely listen to his body's internal sounds. The developed device should be easy to construct, made from common and cheap materials so that it will be aproachable to all people around the glob regardless their financial abilities and location, and increase the medical equality by making the medicine reachable to people on different parts of the world.

During the research several methods have been tried and tested to reach the final model of the IoT stethoscope which is able to perfectly record the internal body sounds. The steps to construct of the IoT stethoscope can be described as follows:

1. Cut the stethoscope tube in the part before it is branched out in order to connect the eartube
2. place a microphone which can be connected to the patient's device in front of the cut tube and fix it.

The detailed layers of the components and the technology options that can be used on each level is presented in Figure 1.

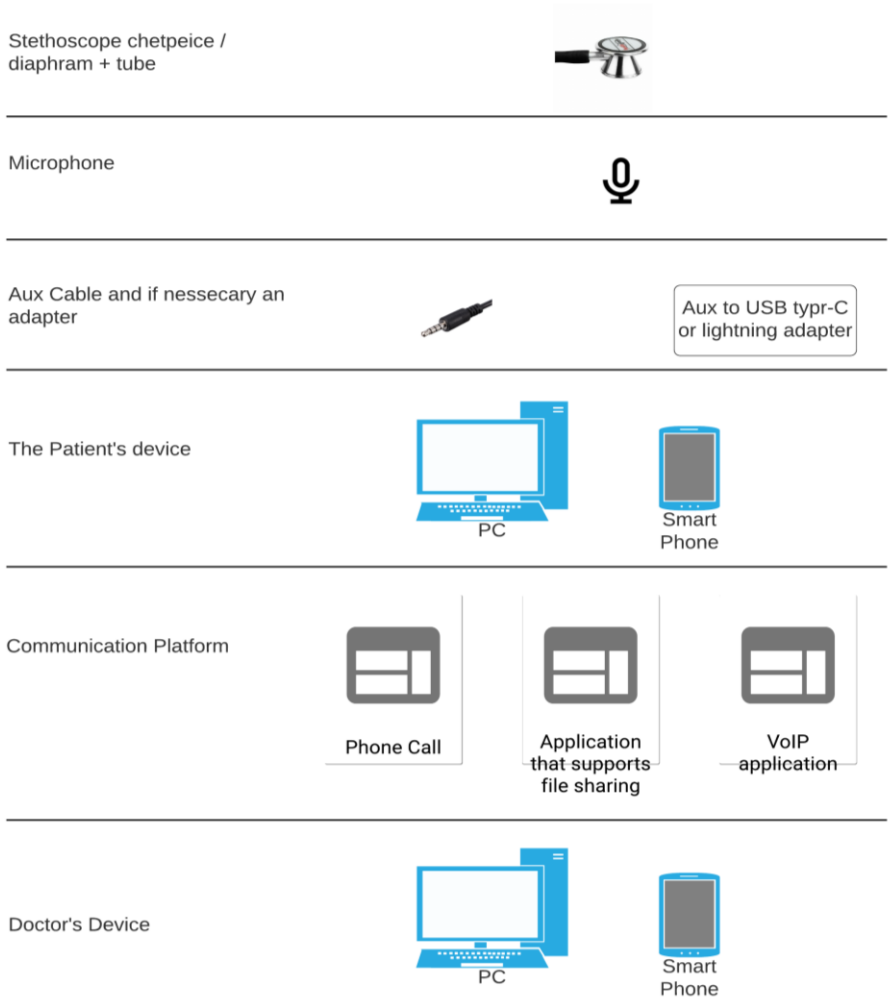

Fig. 1. The detailed layers of the IoT stethoscope system components

The stethoscope chestpiece layer. In our development, we will use an acoustic stethoscope's chestpiece for detecting the body's internal sounds. Different models of acoustic stethoscopes are available in the market that vary in acoustic clarity, affordability, comfort, and reliability. The quality of the chosen stethoscope based on which we will build our device will have huge impact our final result, as if the stethoscope used won't detect a certain sound, we will not able to transfer it to the doctor sitting on the other side of our system.

Typically the stethoscopes detects body sounds starting from 20 Hz. The heart sounds frequency of is between 20 and 150 Hz. It is commonly admitted that lung sounds' frequency is in the frequency range [50, 2500 Hz], and that tracheal sounds can reach up to 4000 Hz. [5-6]

On each level of our implementation, we have to make sure the technologies and components we select do not attenuate frequencies in that ranges, especially frequencies in the lower limits where the heart bit sounds exist. Otherwise, the overall implemented system will be insensitive toward that sounds and will not transfer that sounds to the doctor.

The microphone layer. Most of the microphones we used today, especially the headphone's microphone, record sounds starting from 200 Hz. That means attenuating all the heart sound, which isn't what we need. In our implementation we have used a lavalier microphone, which records sounds starting from 20 Hz. In order to attach the Lavalier microphone to the cut stethoscope tube, we have removed the windscreen foam cover and used a paper scotch to hermetically fix the microphone.

The communication platform and software layer. The developed system can use different communication platforms such as phone calls, VOIP or file sharing applications. For a best productivity, the patient and the doctor can have a video call, during which the doctor tells the patient where to place the stethoscope on the patient's end, and by seeing the actual place of the stethoscope tell the patient how to correct the place if necessary. However, in places where internet connection is slow, such as on top of mountains or villages.

If the patient is in a place where internet connection is slow, he can connect to a doctor through a phone call in order to share the stethoscope sound, or record the stethoscope sound and send it to the doctor.

The software on patient's device place an important role too. For example, when testing the device to record the heart sounds on PC we had to enter the card sounds settings and turn off the input noise cancelation feature. This feature cancels the low frequency sounds (high pass filter) from the signals they get from the microphone to reduce noise in the recorded sound and improve its quality. But this isn't what we need for this specific system.

Most voice/video call applications today have noise cancelation feature too. Only few ones offer the ability to turn off that feature which should be used in this system.

The Doctor on his PC listens to the patients internal body sounds and puts the diagnosis and the medication.

Results. Based on the technology researches the developed IoT stethoscope has been implemented and realized. The implemented device demonstrated perfect results in the preliminary tests. The photo of the implemented stethoscope is presented in figure 2.

Fig. 2. The implemented IoT stethoscope

The use cases of the implemented IoT stethoscope. The implemented stethoscope can be used in the following situations

1. Online treatment of patients who leave in villages where no doctors are available, by a doctor who seats in front of his PC in other place of world.
2. Providing online medical care to hikers in emergency situation.
3. Providing online medical care to patients in epidemic situations, without risking the doctor's health.

Conclusions. From what is presented above we can conclude:

1. Categories of modern stethoscopes have been researched.
2. The IoT stethoscope has been developed, and its components' detailed levels have been presented.
3. The technologies that can be used on each layer of the developed stethoscope have been researched.
4. Based on the technology researches the developed IoT stethoscope has been implemented and realized.

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