

Demo Abstract: AI Stethoscope for Home Self-Diagnosis with AR Guidance

Kaiyuan Hou, Stephen Xia, Junyi Wu, Minghui Zhao, Emily Bejerano, and Xiaofan Jiang

Columbia University

{kh3119, sx2194, jw4173, mz2866, eg3205}@columbia.edu, jiang@ee.columbia.edu

ABSTRACT

Cardiopulmonary ailments are a major cause of mortality. Stethoscopes are one of the most important tools that healthcare professionals use to screen patients for a variety of ailments, especially those related to the heart and lungs. Despite the growth of digital stethoscopes on the market, it takes years of training to properly use stethoscopes to listen for abnormal sounds within the body. In this demonstration, we present an intelligent stethoscope platform that makes stethoscopes more accessible to the general population. Our platform utilizes augmented reality (AR) to provide real-time guidance on where to properly place the stethoscope on the body, enabling the general population to screen themselves for ailments.

CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**.

KEYWORDS

digital stethoscope, human computer interaction, smart home

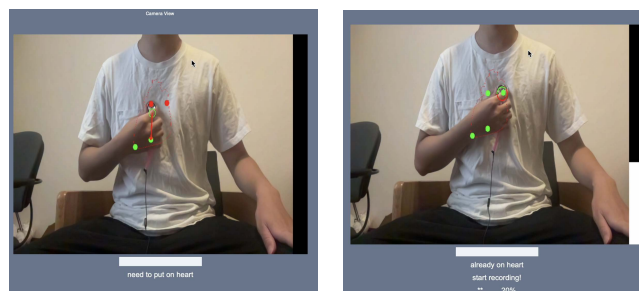
ACM Reference Format:

Kaiyuan Hou, Stephen Xia, Junyi Wu, Minghui Zhao, Emily Bejerano, and Xiaofan Jiang. 2022. Demo Abstract: AI Stethoscope for Home Self-Diagnosis with AR Guidance. In *The 20th ACM Conference on Embedded Networked Sensor Systems (SenSys '22)*, November 6–9, 2022, Boston, MA, USA. ACM, New York, NY, USA, 2 pages. <https://doi.org/10.1145/3560905.3568082>

1 INTRODUCTION

Preventative care is expensive and not accessible to many people in the world. More than 26,000 Americans die each year due to a lack of health insurance [1]. This figure is even larger in underserved regions. There are many works that aim to improve access to healthcare by enabling the general population to monitor their health and safety outside of doctor visits [2–6]. However, there are still many open problems in this domain.

Cardiopulmonary diseases cause some of the highest rates of mortality worldwide, and tools, such as thermometers and glucometers, cannot reliably be used to detect these pervasive ailments. Typically, healthcare providers use stethoscopes to perform auscultation, or listen for abnormal sounds internal to the body, to screen for cardiopulmonary ailments. In recent years, there has



(a) Guides user with stethoscope (green circle) to the next auscultation point (green dot). (b) Starts collecting sounds when stethoscope has been placed at desired auscultation point.

Figure 1: Examples of guidance.

been a rapid growth in digital stethoscopes for telemedicine [7, 8]. However, it takes many years of training and expertise to be able to properly use a stethoscope, know where to place the diaphragm, and distinguish between normal and abnormal sounds. Our vision is to enable anyone to reap the benefits of stethoscopes without visiting doctors by incorporating AI-assisted guidance to identify correct body points for auscultation and acoustic intelligence, drawn from previous works in cyber-physical systems [9–11], to automatically detect potential ailments.

The Eko stethoscope is the state-of-art digital stethoscope that offers automated heart murmur detection. However, this stethoscope does not provide automated guidance, and we observe a high rate of false positive detections. Additionally, this stethoscope costs more than \$300, which is relatively high.

In this work, we present an intelligent AI-based stethoscope that improves the accessibility of stethoscopes to the general public. As shown in Figure 1, our platform utilizes the camera on the computer and augmented reality (AR) to guide users on where to place the stethoscope and what actions to perform in real-time, in absence of a healthcare provider. Our platform then automatically analyzes the observed audio signals observed from the stethoscope to detect abnormal sounds. Additionally, we build a stethoscope using inexpensive components, totaling 18 USD. Our intelligent stethoscope platform moves one step towards enabling universal health screening, especially for under served regions.

2 SYSTEM DESIGN

Figure 2 shows the data processing pipeline of our AI-based stethoscope platform. The system utilizes the camera from the computer and our custom stethoscope to provide appropriate guidance and robustly detect ailments. Auscultation mainly consists of two parts: placing the stethoscope at appropriate locations (auscultation points) on the body and making a diagnosis based on the sound

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).
SenSys '22, November 6–9, 2022, Boston, MA, USA
© 2022 Copyright held by the owner/author(s).
ACM ISBN 978-1-4503-9886-2/22/11.
<https://doi.org/10.1145/3560905.3568082>

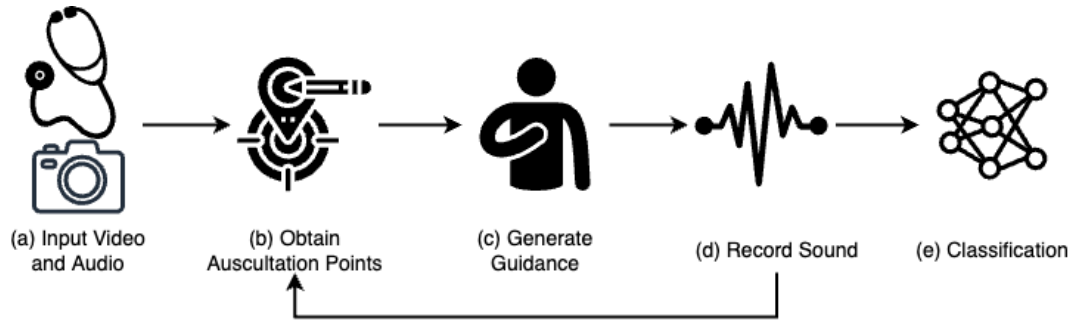


Figure 2: Data processing pipeline.

from stethoscope. Our platform will first leverage the camera of the computer to determine the location of the next auscultation point and provide visual and audio cues to guide users on where to place the diaphragm of the stethoscope. Once the user places the stethoscope in the correct area, the stethoscope will record and analyze internal body sounds for abnormalities and ailments.

2.1 Auscultation Points

In this work, we focus mainly on detecting heart and lung ailments, which involve moving the stethoscope to areas around the heart. First, we obtain the coordinates of the user's shoulders after applying an affine transformation; this removes variations caused by how the user is sitting. We use the location of the shoulders to then estimate the location of the user's heart and approximate the locations of auscultation points based on the heart and shoulders.

2.2 Guidance Generation

Our platform provides guidance to account for two challenges. First, there is still significant deviation of the estimated auscultation points even after applying an affine transformation. As such, the first class of instructions involve asking users to maintain their sitting position to obtain the most accurate auscultation points. The second form of guidance involves guiding users on where to place the stethoscope using an AR overlay, as highlighted in Figure 1.

2.3 Disease Classification

Once the stethoscope is at the appropriate auscultation point, we leverage two deep neural networks to classify heart and lung ailments, both of which were trained with widely available datasets. Both neural networks take as input the spectrogram representation of the audio signals, treating them as images to classify.

3 DEMONSTRATION DESCRIPTION

In this demonstration, we will show how our platform efficiently guides users to find auscultation sites to place the stethoscope. Users will be asked to hold the bell of the stethoscope and follow the guidance instructions provided by the application, which will guide them to analyze their heart and lungs. At the end of the examination, a report of the detected abnormalities will be displayed.

ACKNOWLEDGMENTS

This research was partially supported by the National Science Foundation under Grant Numbers CNS-1704899, CNS-1815274, CNS-1943396, CNS-1837022, and CMMI-2218809. The views and conclusions contained here are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of Columbia University, NSF, or the U.S. Government or any of its agencies.

REFERENCES

- [1] Janice Hopkins Tanne. More than 26 000 americans die each year because of lack of health insurance. *BMJ: British Medical Journal*, 336(7649):855, 2008.
- [2] Dezhi Hong, Ben Zhang, Qiang Li, Shahriar Nirjon, Robert Dickerson, Guobin Shen, Xiaofan Jiang, and John A. Stankovic. Demo abstract: Septimu – continuous in-situ human wellness monitoring and feedback using sensors embedded in earphones. In *2012 ACM/IEEE 11th International Conference on Information Processing in Sensor Networks (IPSN)*, pages 159–160, 2012.
- [3] Daniel de Godoy, Bashima Islam, Stephen Xia, Md Tamzeed Islam, Rishikanth Chandrasekaran, Yen-Chun Chen, Shahriar Nirjon, Peter R. Kinget, and Xiaofan Jiang. Paws: A wearable acoustic system for pedestrian safety. In *2018 IEEE/ACM Third International Conference on Internet-of-Things Design and Implementation (IoTDI)*, pages 237–248, 2018.
- [4] Kaiyuan Hou, Yanchen Liu, Peter Wei, Chenye Yang, Hengjiu Kang, Stephen Xia, Teresa Spada, Andrew Rundle, and Xiaofan Jiang. A low-cost in-situ system for continuous multi-person fever screening. In *2022 21st ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN)*, pages 15–27, 2022.
- [5] Stephen Xia, Daniel de Godoy Peixoto, Bashima Islam, Md Tamzeed Islam, Shahriar Nirjon, Peter R. Kinget, and Xiaofan Jiang. Improving pedestrian safety in cities using intelligent wearable systems. *IEEE Internet of Things Journal*, 6(5):7497–7514, 2019.
- [6] Stephen Xia, Jingping Nie, and Xiaofan Jiang. Csafe: An intelligent audio wearable platform for improving construction worker safety in urban environments. In *Proceedings of the 20th International Conference on Information Processing in Sensor Networks (Co-Located with CPS-IoT Week 2021)*, IPSN '21, page 207–221, New York, NY, USA, 2021. Association for Computing Machinery.
- [7] Aparna Lakhe, Isha Sodhi, Jyothi Warriar, and Vineet Sinha. Development of digital stethoscope for telemedicine. *Journal of Medical Engineering & Technology*, 2016.
- [8] Vidushi Mahajan, Tanvi Singh, and Chandrika Azad. Using telemedicine during the covid-19 pandemic. *Indian Pediatrics*, 2020.
- [9] Stephen Xia, Daniel de Godoy, Bashima Islam, Md Tamzeed Islam, Shahriar Nirjon, Peter R. Kinget, and Xiaofan Jiang. A smartphone-based system for improving pedestrian safety. In *2018 IEEE Vehicular Networking Conference (VNC)*, pages 1–2, 2018.
- [10] Stephen Xia and Xiaofan Jiang. Pams: Improving privacy in audio-based mobile systems. In *Proceedings of the 2nd International Workshop on Challenges in Artificial Intelligence and Machine Learning for Internet of Things, AIChallengIoT '20*, page 41–47, New York, NY, USA, 2020. Association for Computing Machinery.
- [11] Stephen Xia and Xiaofan Jiang. Ava: An adaptive audio filtering architecture for enhancing mobile, embedded, and cyber-physical systems. In *2022 21st ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN)*, pages 118–131, 2022.