Instructions:

- The information you provide in the following sections should **not exceed 2 pages**
- You may append figures or tables on **one extra page** if you wish.
- Please, respect carefully the following structure: Background, Methodology, Results, Discussion and Conclusion. Submissions will be reviewed with equal emphasis on each element.
- If your project is about designing a piece of hardware, a template can be found on the event webpage.

Start of the 2 page limit

Background : The form and function of the stethoscope has changed very little in the past two hundred years. Digital stethoscopes that have been developed so far have failed to make a significant impact, due to their size, cost and the requirement of a trained operator to make a diagnosis. However, there are a number of potential benefits to a digital stethoscope: recordings can be stored and shared, and most importantly, machine learning can be used to analyze the data to make automated diagnosis.

This project aims to research, design and develop the prototype hardware for a next-generation digital stethoscope. The key innovation is to allow automated diagnosis, with emphasis on price and size.

Methodology: I first investigated various methods of recording heart sounds using microphones, with the aim of producing recordings of sufficient quality for automated diagnosis. The trade-off between microphone cost, size and type and the influence of microphone position within the tube on recording quality were considered along with ways of reducing signal-to-noise ratio (SNR).

The recordings were represented in the form of phonocardiograms, autocorrelation functions and power spectral densities. These were compared with recordings made from two current commercially available digital stethoscopes. Several ways of determining the quality of a recording were used: SNR of fundamental heart sounds, frequency domain analysis of the signal using power spectral densities, and quality classification using a machine learning algorithm.

Next a current digital stethoscope that met some of the “Smart Stethoscope” system requirements was reverse engineered. The key components were identified, the benefits and shortfalls of the system considered and integrated into the prototype design.

Results: It was found that good quality recording, comparable to that of existing digital stethoscopes, can be achieved using cheap electret microphones located in-line with the stethoscope tube. We found that a very small electret microphone can be used to make recordings of sufficient quality for automated diagnosis. A prototype stethoscope recording system was developed using an Arduino Nano as an analogue-to-digital converter, and an electret microphone with a pre-amplifier PCB as the recording apparatus (see Figures 1 and 2). Customized 3D printed parts make the system compatible with existing analogue stethoscope. By the quality metrics defined in the Method section, it is shown that good quality recordings can be made with the prototype system.

Discussion: I have clearly demonstrated that there is potential to create a recording system that is much cheaper than other digital stethoscopes on the market. Further, the system can make recordings of sufficient quality for automated diagnosis, meaning that non-professionals can gain insight from the system. This is particularly useful for early-stage identification of heart and lung conditions. The low-cost of the system gives it the potential to be available in areas where access to medical professionals is limited. A way to make a system even cheaper and more flexible is to allow analogue stethoscope compatibility. This is also likely to increase uptake among physicians, who prefer to use devices that they are familiar with.

Further improvement to the prototype system could include incorporating all of the electronic components onto a custom printed circuit board in order to reduce noise, and to use a Bluetooth low-energy enabled microcontroller to transmit the signal wirelessly to a PC or phone.

Conclusions:

- The project demonstrates that it is possible to make heart sound recordings of sufficient quality for automated diagnosis using cheap and readily available components
- The properties of different microphones, such as their sensitivity and response field, have a significant influence on the recording outcome
- From the perspective of an automated classifier, signals can be of sufficient quality for diagnosis ven if there is significant audible noise present provided that the noise is of a high enough frequency so as not to interfere with heart sounds
- Offering digital recording apparatus that is compatible with analogue stethoscope will reduce costs and may be appealing to professional users.

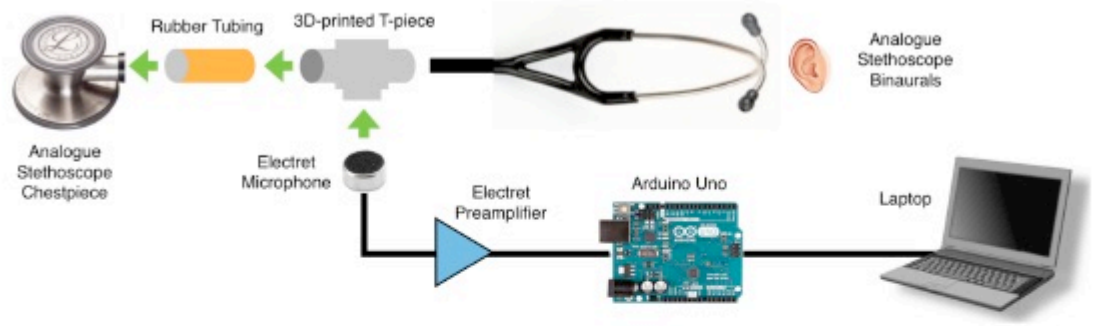

Figure 1 – *schematic of electret recording using an Arduino Uno as a data logger. The power to the board and the serial interface to the PC are provided by the USB serial port.*

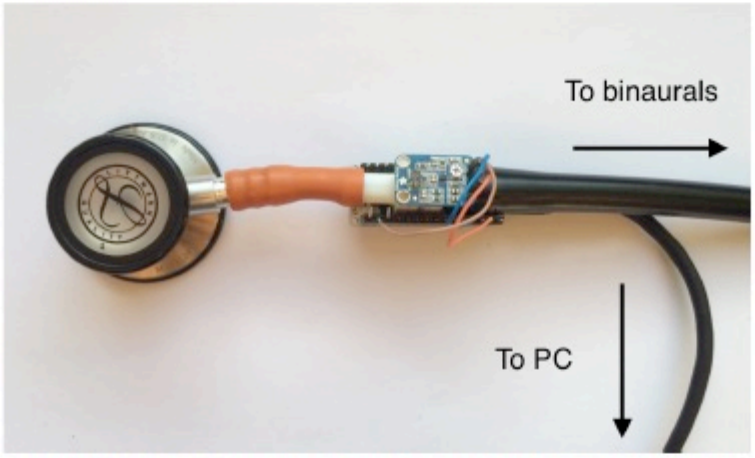

Figure 2 - *prototype design of the smart stethoscope incorporating an Arduino Nano and an Adafruit electret preamplifier.*