A Non-Invasive Wireless Respiratory Monitoring System for Animals

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*Abstract*—This paper presents and assesses the device of an undergraduate engineering research project. We explain the purpose and need for such a device. Next, we describe the design and construct of the device. In addition, we describe the test plan, setup, and result of the device. We comment on the future improvement and development of the device.

# Introduction

The main objective of the project is to develop a biomedical device that can noninvasively monitor a dog’s heart rate using conductive fabric.

There has been much progress in wearable sensors for animal monitoring in terms of technology and applications. The latest technologies include RFID tags, implants, and other non-invasive methods. On the application side, these wearable sensors are able to detect animal sweat constituents, measure body temperature, observe behavior and movement, detect stress, analyze sound, detect pH, prevent disease, detect analytes and detect presence of viruses and pathogens, according to an article on sciencedirect.com[1]

Along with the advancement of technology there is also an increase in demand for wearable monitoring devices for animals in pet industry, animal husbandry and animal protection fields. According to Wearable technology for animals 2017-2027: Technologies, Markets, Forecasts [2], “The animals most likely to employ wearable electronics in volume in the next decade are those controlled by humans notably certain livestock, work animals and pets that we identify but conservation of wild species will also increase in number and sophistication.” One specific field of application we are looking into is the animal monitoring studies for neuroscience and psychology. Numerous researches have shown a relationship between respiratory activities and psychological activities in human beings. According to an article on ScienceDaily[3], “There's increasing physiological evidence connecting breathing patterns with the brain regions that control mood and emotion. Now researchers have added neurons associated with the olfactory system to the connection between behavior and breathing. Connecting patterns in these interactions may help explain why practices such as meditation and yoga that rely on rhythmic breathing can help people overcome anxiety-based illnesses.” Another article: Respiratory Changes in Response to Cognitive Load: A Systematic Review [4] published on the NCBI website also indicates the existence of such relationship. Therefore, we believe that such relationship not only exist in human beings but also in various animals and they are definitely worth looking into. A reliable wearable apparatus for real time animal respiratory monitoring can certainly be beneficial for this kind of research.

The recent advancement of conductive fabric opens up a brand new approach to the development of wearable monitoring devices. There are already numerous types of conductive fabric materials available on the market, such as pressure sensitive conductive rubber and metal coated woven fabric that can be constructed as capacitive sensors. Several applications have already shown their potential in wearable technology. In our case, these fabrics are

There are numerous other breathing and heartbeat monitoring techniques as well. <> Compared with their method our approach <>

The same technology can be applied in heartbeat monitoring as well as indicated in <>

Our device can really simplify the dog breath rate sensing technology making them more affordable and reliable animal psychological studies. The approach towards this project is to measure the breadth rate of a dog which is related to the movement of the dog’s chest. The resistance of the fabric will vary as the dog’s chest stretches the fabric. Using resistance to voltage convert circuitry, we generate a voltage signal that is correlated with the movement of the dog’s chest. This signal is captured using a microcontroller and then together with the temperature readings from a temperature sensor they will be sent over to a computer wirelessly for further process and analysis. This custom-made sensor-microcontroller device is attached to a dog harness. Finally, in our computer, we would filter out all the noises and measure the number of pulses which represents the breath rate and ultimately heart rate from the signal. The recorded data can be used in analyzing, diagnosing and improving the dog’s health conditions.

# Design and Construct

## Hardware

The device mainly consists of a rubber cord stretch sensor, a microcontroller with a Wi-Fi module, a 350mAh battery and a dog harness.

The stretch sensor will be tightly wrapped around the test subject’s chest and capture the expansion and contraction movement as an electric signal which will then be sent to the microcontroller. The microcontroller is an ESP32 by Espressif Systems. It is responsible for compiling the data and send them to PC via Wi-Fi. The data was later received and processed by MATLAB. The whole device was mounted on the dog harness.

![图片包含 文字

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## Software

The microcontroller program is responsible for data logging and transmission. <elaborate on logic>

图片包含 文字, 地图

描述已自动生成

The PC software was written in MATLAB which contains 3 stages. Noise filtering, peak counting, and result in plotting and logging. <elaborate on logic>

图片包含 文字

描述已自动生成

![图片包含 屏幕截图

描述已自动生成](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RDaRXhpZgAATU0AKgAAAAgABAE7AAIAAAAFAAAISodpAAQAAAABAAAIUJydAAEAAAAKAAAQyOocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAE93ZW4AAAAFkAMAAgAAABQAABCekAQAAgAAABQAABCykpEAAgAAAAMyMAAAkpIAAgAAAAMyMAAA6hwABwAACAwAAAiSAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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# test set up and results

The tests were separated into 2 stages: the first one being the electrical functionality test; the second one being the biological test on a test subject.

## Stage one electrical function test

In the first stage, we will power on the device and manually stretch the sensor for 15 seconds. In these tests, we seek to verify whether the sensor sensitivity is good enough for the MATLAB to find peak algorithm to count the number of pulses. Also, we verified whether the BLE data link is properly working.

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Fig. stage one setup

## Stage one results图片包含 地图 描述已自动生成图片包含 地图, 文字 描述已自动生成图片包含 地图 描述已自动生成

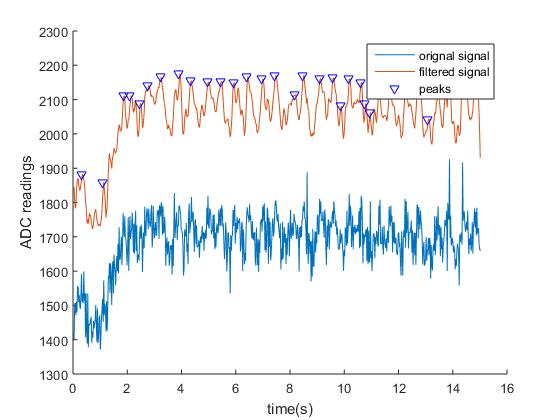
## Stage two biological test

In the second stage, the test included a test subject (a golden retriever) provided by A Nickerson. During the test, we strap the dog harness with the device onto the test subject and measure the breath rate for a certain amount of time. We conducted 2 groups of tests. In group one we conducted the experiment with the dog being idle and take the measurement for 15 seconds. In the second group, the dog can run freely and we take measurements for 60 seconds.

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Fig. stage 2 setup



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# discussion and summery

Success on electrical test and static biological test.

Problem with measurements when the dog is moving

Future improvements.

##### Acknowledgment *(Heading 5)*

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##### References

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