Tele-Rehab For Dysphagia

2019 Group #11-14

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Abstract

Dysphagia (swallowing disorder) is increasingly prevalent in older adults and patients with neurological disorders. However there has not been much research on Dysphagia as compared to other diseases (eg. Parkinson's Diseases). Furthermore, many of the current diagnosis methods are too expensive and are inefficient. In addition, current rehabilitation methods are inconvenient for patients and drains manpower. Hence, there is a need for a better alternative that is more cost-efficient, requires less manpower, easy to perform, requires less hospital visits and is more convenient for the patients. In this work, a system of telerehabilitation of Dysphagia, consisting of an Arduino microprocessor and user interface was developed. Sound frequencies of swallowing was sent to the Arduino, which processed the data into a user interface for speech therapists to analyse. Experimental trial runs demonstrated the feasibility of the proposed system.

Introduction

Dysphagia is the medical term for any difficulty when swallowing. Dysphagia is a common condition, affecting around 14 percent of the population over 50 years of age (Kawashima, K., et al, 2004) and in Singapore, over one in five older adults are affected by it (Felicia Choo, 2016). Despite it being a common condition, there hasn't been much research into this area, and is largely unknown to the public. The main complication of Dysphagia is coughing and choking, which can lead to pneumonia. For a person with Dysphagia, there's a risk of food, drink or saliva going down the "wrong way". It can block the airway, making it difficult to breathe and causing the patient to cough or choke. As such, patients may also develop a fear of choking, thus they might stop eating and drinking, which could lead to dehydration and malnutrition. More threateningly, Dysphagia after stroke carries a threefold increased mortality risk and a sixfold to sevenfold fold increased risk of aspiration pneumonia (Singh, S. et al, 2006).

There are 3 main types of Dysphagia: Oral dysphagia (high dysphagia) — the problem is in the mouth, sometimes caused by tongue weakness after a stroke, difficulty chewing food, or problems transporting food from the mouth, Pharyngeal dysphagia — the problem is in the throat. Issues in the throat are often caused by a neurological problem that affects the nerves (such as Parkinson's disease, stroke, or amyotrophic lateral sclerosis), Esophageal dysphagia (low dysphagia) — the problem is in the esophagus. This is usually because of a blockage or irritation (Christian Nordqvist, 2017) In all forms of Dysphagia, there are obstructions in swallowing. As such, there could be potential sound frequency anomalies in analysing data of patients with Dysphagia.

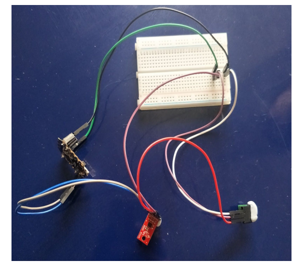
Current methods of diagnosis include endoscopy, barium radiology and manometry, which are expensive, harmful to human health and inefficient. Endoscopy entails risk such as perforation of the gut wall. The risks of endoscopy are worth taking only when the procedure is worth doing and when the benefits outweigh the risks (Palmer, K. R. , 2007). Moreover, endoscopy is costly considering the high risk and advanced equipment used. Barium radiology meanwhile subjects the patient to x-ray, hence there will be a risk of radiation. Being the cheapest of all, barium radiology costs $300-$450 USD ($400-$600 SGD) (Cirino, E, 2017) ; a sizeable amount. Lastly, manometry also exposes the patient to risk as it exposes the individual to infection by the intrusion of a metallic equipment into a patient's stomach and concurrently caused discomfort in the individual. Thus, an appraisal on the current methodologies of dysphagia diagnosis and treatment is needed (Kaindlstorfer A, et al., 2016); and thus improvement is required.

To aid in the recovery of Dysphagia patients, rehabilitation exercises were developed to monitor patient's recovery. However, current methods were inconvenient for patients, as it required multiple hospital visits. Current methods of rehabilitation also involved specific medical personnel using the apparatus, which was a waste of manpower and extremely inefficient. Lastly, patients were exposed to unnecessary risks, further prompting a change in dysphagia diagnosis and rehabilitation. As such, patients may start to neglect their recovery and their conditions would start to worsen overtime. Telerehabilitation solves most of these problems, while still retaining its purpose of facilitating the patient's recovery. (TeleHealth. n.d.)

Therefore, this project had attempted to create a system of telerehabilitation that could monitor patient's recovery progress and facilitate in patient's rehabilitation exercises. The device would be cost-efficient for mass production in the future, and it would also be convenient for patients, while still serving its purpose.

Solution Design

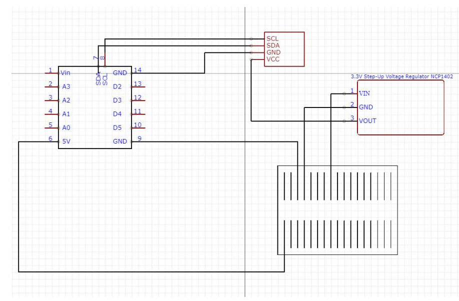
The objective of the solution design was to monitor the progress of Dysphagia with the use of sensors to detect any irregularities. A system of tele-rehabilitation had been implemented, which taught patients how to perform the rehabilitation exercises and monitor them performing these exercises. The solution design was split into two main phases: Data Collection, and the User Interface.



Data Collection

The first phase of the prototype involved collecting data from the Arduino.

<u>First Prototype: 9 DoF</u>



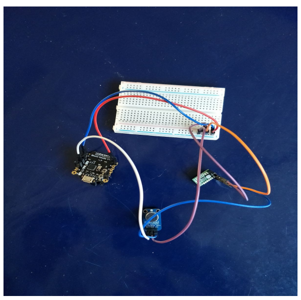
The first prototype involved the use of a 9 Degree of Freedom (9DoF) Sensor. The 9 DoF consists of the gyroscope, accelerometer and magnetometer, each of the following collects 3-axis raw data. The data collected were then processed into 3 readable values: Yaw, Pitch and Raw, which had been analysed to detect any possible irregularities for patients with Dysphagia. The rationale behind the 9 DoF was to measure the movement in the swallowing process.

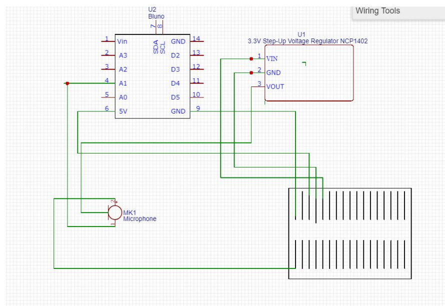
Major components of the 9DoF circuit consists of a Bluno Beetle Arduino microprocessor, a 9DoF Sensor Stick - LSM9DS1, and a 3.3V Voltage Regulator

However, a major setback of the 9 DoF Sensor Stick was that most data collected was irrelevant. For example, the magnetometer readings were irrelevant because there is no magnetic field involved in the swallowing process. The accelerometer readings were also insignificant as swallowing would involve minimal movement, and the accelerometer was not sensitive enough to pick up the tiny movements. Furthermore, there were not much significant overall changes observed in the swallowing phase. As such, the 9 DoF was not suited for the task.

Second Prototype: Microphone frequency sound sensor

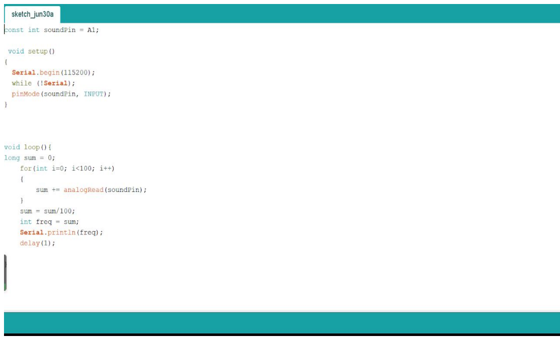
The second prototype involved the use of the Electret microphone sound frequency sensor. The sensor is capable of collecting data of 20-20000Hz (normal audible hearing frequency of humans), thus it is capable of picking out swallowing sounds. The microphone sound sensor is also equipped with an amplifier (MAX9814), which has filters background noise. This reduced background sound irregularities that allowed data of better quality to be collected and analysed. The rationale behind the microphone sound sensor was to detect the sound frequency changes in the swallowing process.





Major components of the microphone sound frequency sensor circuit consists of a Bluno Beetle Arduino microprocessor, a Electret Microphone Amplifier - MAX9814 with Auto Gain Control, and a 3.3V Voltage Regulator

Arduino Code



```
sketch_jun30a
const int soundPin = A1;

 void setup()
{
  Serial.begin(115200);
  while (!Serial);
  pinMode(soundPin, INPUT);
}


void loop(){
long sum = 0;
    for(int i=0; i<100; i++)
    {
        sum += analogRead(soundPin);
    }
    sum = sum/100;
    int freq = sum;
    Serial.println(freq);
    delay(1);
```

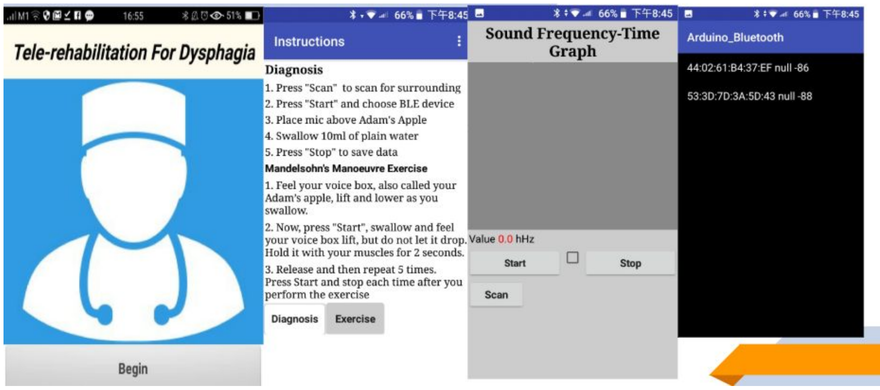
The arduino receives data from the sound frequency sensor and packages the data into uint8_t (unsigned integer of length 8 bits in hexadecimal values) format to send the data out via BLE as BLE can only transmit a maximum of 20-bit.

In order to plot a useful graph for analysis, raw data collected was divided by 100 to convert hertz to hectohertz to reduce sensitivity of data collected so that more prominent peaks could be observed for proper analysis.

User Interface

Once the data is collected on the Arduino and sent out via BLE, the data would be displayed on a user interface for the user and therapists to view.

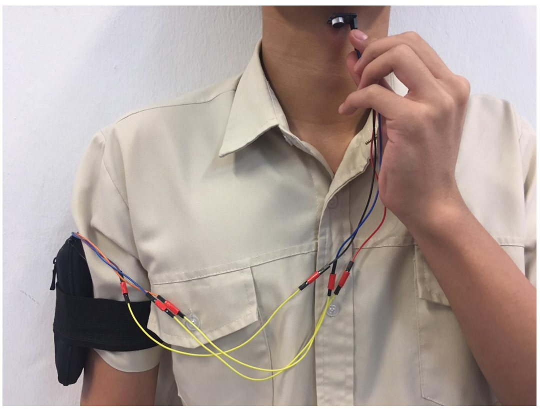
The user interface is an Android app created using MIT App Inventor. This application is responsible for the presentation of the data in the form of a graph for the therapists to evaluate the patient's condition and monitor their rehabilitation progress.



The application serves to guide patients through the rehabilitation process through detailed and self-explanatory instructions in order to ensure maximum efficiency. Patients are required to perform their exercises/diagnosis with the use of the arduino device to monitor their swallowing. In order to do so, patients can simply click "Scan", "Start", select "Bluno" and the patient can start the exercise. The patient is then able to stop the real-time graph of their swallowing when it has been finished and a screenshot would be automatically saved to a directory that one could customize, which would then be sent to the therapists for detailed analysis and evaluation of the patient's condition. To ensure user-friendliness, different languages were also incorporated into our application, English and Chinese, in order to cater to different demographics.

Prototype Design

The prototype was designed in order to ensure portability and user's comfortability, we have encased our circuit within a mini pouch. The microphone was separated from the circuit using extended jumper wires. In order to wear the device, patients would simply have to wrap the velcro strap around their biceps, and position the microphone sensor above the Adam's Apple on the throat (or at the top of the throat, below the chin) to start data collection.

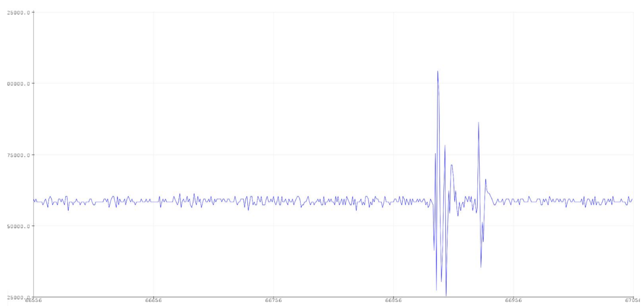


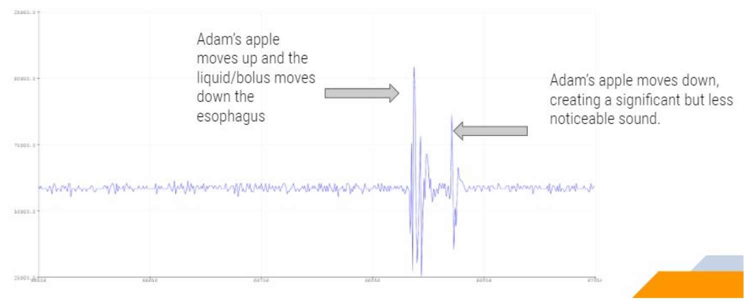
Results and Discussion

Data Analysis

For the analysis of data, tests had been performed using the inbuilt serial plotter inbuilt in the Arduino IDE, and collected various sets of data on ourselves. Testing had also been standardised to include the swallowing of 10ml of plain water and the placing of the sensor on the adam's apple.

The graph is a sound frequency (hectohertz) against time (seconds) graph. The graph obtained would thus allow therapists and doctors assess the current condition on the patient.

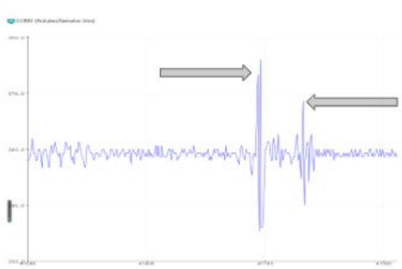




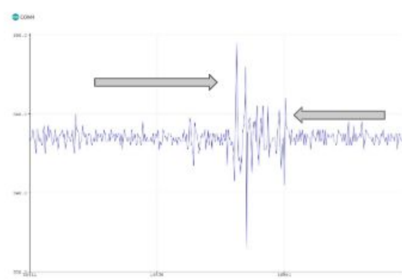
From the graph above, it was observed that there are two main peaks in the graph; the first being the laryngeal prominence (Adam's Apple) moving up as food travels through the esophagus, and the second after the laryngeal muscles have relaxed. This was the average graph obtained after 100 standardised tests on different members in our group.

Testing on Different Age Groups

Considering that the elderly were more susceptible to dysphagia and that the graph might be different due to slower swallowing that comes with age, tests have been carried out at on a sample from that age group (above 65). By doing so, a more accurate threshold could be determined for older patients, providing the doctors more accurate information on the state of the patient.



Standard Graphs



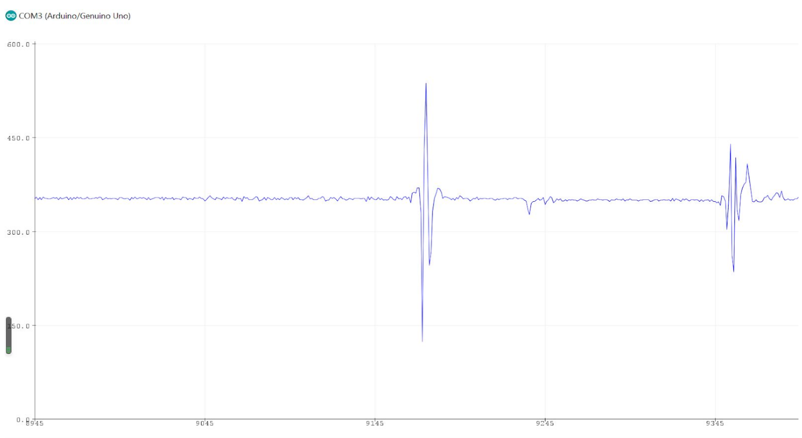
Elderly

As shown, the general pattern conformed to a standard graph, but the central portion was a bit more erratic as we see greater disturbances. This might be because their swallowing was not as smooth due to old age, but does not dictate that the person was suffering from dysphagia. As such, the device could still be used for the elderly.

Mandelsohn’s Maneuver (Rehabilitation Exercise)

In the app, there is a simple rehabilitation exercise: Mandelsohn’s Maneuver, which involves the patient holding his/her swallow for 2-3 seconds per rep (to be repeated 12 times per day).

The programme also enables therapists to track patients performing their daily rehabilitation exercises remotely. Generally, everytime the Mandelsohn’s Maneuver is performed, a pattern will be observed in the data collected, which will notify the doctor the progress of the patient’s dysphagia and whether he/she was performing the exercise correctly. This will also enable the doctors to ensure that patients are doing their exercises as instructed.



Because the maneuver entails the holding of the adam’s apple, the swallowing graph obtained was a normal swallowing graph with a long interval in the middle. The first and second peak, just like the original graph, refers to the sound made of the adam’s apple moving up (bolus/liquid moving down the esophagus) and it moving down respectively.

Summary

While tests have not been carried out on dysphagia patients due to ethical reasons, results collected have led us to theorise the following factors that could determine whether an individual has Dysphagia:

1. Ability to hold their swallow in the Mandelsohn's Maneuver (The holding process trains and exercises the swallowing muscle that has atrophied in dysphagia patients)
2. Time interval between the two peaks identified during the swallowing phase (Dysphagia patients have difficulty swallowing, hence it delays their swallow as it takes a longer time for their muscles to contract or move)

Limitations

Tests have not been carried out on actual Dysphagia patients, hence there is no proper evaluation of the effectiveness if used in the real world contexts. Further research could thus be done with actual Dysphagia patients to derive more accurate data.

Due to limitations of the current programme used to code the App, values collected by the app were in encrypted form and were unable to be translated into readable data to plot a graph with the user interface. Thus, future work could be done using other programmes, such as Swift (CoreBluetooth).

Users may find it inconvenient as they have to repeatedly record their readings as they perform their exercises. Moreover, users could easily generate 20 graphs per day, which makes it difficult for therapists to critically analyse the graphs - some could be fluke graphs. Future work could thus be done in sieving out accurate data only for the therapists to analyse through the use of Big Data and AI.

Conclusion

In essence, tests have shown that it was possible to identify Dysphagia based on the sound frequencies of swallowing patterns. Detailed analysis of graphs for normal swallowing and the Mandelsohn's maneuver had been performed, and a possible wireless telerehabilitation system that is able to monitor the patient's recovery progress and ensure that patients are performing their exercises as instructed to aid in their recovery had been developed. However, the conclusions were not definitive as tests had not been carried out on real patients and the conclusions were mere hypothesis. Thus, the current prototype could be improved through definitive testing with real patients.

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Acknowledgements

We would like to thank our teacher mentor, Mrs Ng Siew Hoon, for the effort put into helping us with any enquiries and our external mentor, Professor Tay to provide us with salient information and invaluable guidance for the exact workings of our project. We would also like to thank the SRC Lab Staff for their supervision and technical guidance. Lastly, we would like to thank the NUS staff and students who have helped us throughout our project and attended to us to their best abilities.