CMPT 340 Project Report: Pulse Oximetry Data Analysis with a Mobile Application (Android)

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Abstract. Obstructive sleep apnea is a sleeping disorder caused by a blockage in the airway during sleep, thereby restricting air flow causing a cessation in breathing. For diagnosis, a patient usually undergoes a Polysomnogram (PSG) test. Notable issues with PSGs include high costs associated with long wait lists due to the lack of technical labs and specialists capable of performing such encompassing testing procedures. Pulse oximetry is a non-invasive alternative in taking the first steps towards sleep apnea diagnosis through analysis of oxygen saturation. Our team has developed Oxylyzer, a mobile application which interfaces with Bluetooth pulse oximeters to analyze the oxygen saturation in accordance with medically approved standards for scoring a possible apnea event overnight. The features and implementation of the application, along with future development ideas, are also discussed.

Keywords: Pulse oximetry, obstructive sleep apnea, home monitoring, mobile application, aided diagnosis.

1 Introduction

Diagnosis of sleep apnea can often be tedious, invasive and time consuming for the patient. Considering that almost 14% of people have sleep apnea, our team thought this would be a good opportunity to try and see if we could develop software to aid in diagnosis [13]. In order to help streamline analysis, the use of a pulse oximeter is a viable non-invasive alternative to help start diagnosing this sleeping disorder. By interfacing a Bluetooth pulse oximeter with a mobile application, our goal was to be able to read and analyze incoming oxygen saturation levels and heart rate levels during sleep. Analysis of these variables would then lead us to conclude whether the patient experienced any apnea events over the duration of the night. Along with clinical testing and overnight oximetry analysis, our application detects whether the patient is at risk of having sleep apnea. Our decision to make this software available on a mobile platform was based off of convenience for the user. If a physician lends their patient a Bluetooth pulse oximeter, the user would only be required to download the mobile application to be able to effectively use the software. It should be noted that pulse oximetry should be only used as a stepping stone towards diagnosis due to limitations in variables and general interference.

2 Sleep Apnea Overview

Sleep apnea is a common sleeping disorder in which there is reduced air flow during sleep caused by a blockage in the airway, which results in a shortness of breath, sometimes causing the person to stop breathing altogether. The upper throat muscles relax during sleep, to the point where the airway is either partially or completely blocked [12]. Each pause in breathing is considered an apnea and during each apnea event the oxygen supply and removal of carbon

dioxide are paused [10]. There are two main types of sleep apnea, obstructive, which is the full stop of airflow to the lungs due to a blockage, and central, in which breathing is reduced due to underlying cardiac issues [11]. Our team will be focusing on identifying obstructive sleep apnea events that occur overnight.

Most people are not conscious of this during sleep as the brain is subconsciously alerted to regain control of the position of your throat and tongue. People are able to breathe again after this without having woken up to do so. This cycle can occur from 5 to 15 times an hour and as a result people start to feel fatigued during the day, often not knowing the reason behind it [14]. Sleep apnea is a significant risk factor for heart disease since the inconsistency in blood oxygen saturation puts a strain on the heart making patients more privy to heart attacks, strokes, as well as premature death. People with sleep apnea tend to be more tired or fatigued during the day, tend to have low productivity and memory problems.

3 Diagnosing Sleep Apnea

There are noticeable symptoms associated with sleep apnea some of them being somnolence and snoring. Patients are also more at risk of developing sleep apnea if they are obese, male and over 50 years of age. Currently, if suspected of having sleep apnea, most physicians will have their patient undergo a Polysomnogram (PSG) test over two nights [4]. This is the gold standard for sleep diagnosis as it takes into account the patients ECG, EEG, oxygen saturation, blood pressure, nasal air flow, leg movements and snoring to be able to properly identify an apnea event during sleep.

Patients are required to sleep two nights at a lab while being continually monitored by a specialist. If the results are conclusive of having sleep apnea, depending on the patient, physicians may recommend treating sleep apnea with weight loss or with the use of a Continuous Positive Airway Pressure device (CPAP) which streamlines a consistent flow of air through the throat during sleep. While this is the leading method in sleep apnea detection, it should be noted that such testing has been known to be expensive, have long wait lists, such labs are not featured in most hospitals, it is often not covered by medicare/insurance and it can be uncomfortable for the patient to be tested out of the comfort zone.

4 Pulse Oximetry: A Viable Starting Point

Pulse oximetry is a non-invasive method of measuring a patients oxygen saturation [1]. A pulse oximeter gages oxygen saturation from a small probe which sends out red and infrared light through the finger which calculates the absorption of haemoglobin [2]. In terms of using pulse oximetry for diagnosis, a study

showed that polysomnography was not significantly better than home oximetry monitoring when predicting how effective the use of the CPAP device would be in counteracting sleep apnea [3]. Pulse oximeters do not require additional supervision and can be used without the need for a technician or lab setting, as seen with the polysomnogram.

5 Accomplishments: Application Implementation and Associated Features

Given a relatively small period of time, and little to no prior knowledge of sleep apnea, our team effectively managed to create a mobile application which can be used to help diagnose the risk of sleep apnea.
In developing our app we have devised a general outline for how the application analyzes and diagnoses patients for the possibility of having sleep apnea. Considering there is no general standardization for interpreting overnight pulse oximetry, we have incorporated methods from polysomnography combined with clinical questionnaires. Naturally clinical scoring will be subjective to each patients discretion.

Our team has also incorporate error checking methods. This includes proper instruction for the use of pulse oximeters in order to garner accurate results.

Implemented bluetooth communication with a pulse oximeter using bluetooth serial port profile, to receive spO2, pulse rate and plethysmograph data in an Android application. The device we use does not support the modern standardized bluetooth health device profiles so we at first had to reverse engineer the correct values from the device. Later we got the serial message format documentation from the supplier and added full support for all the device data including accounting for accuracy readings and discarding bad data.
We created a custom graph display page to show in real time the users spO2 and pulse rate readings side by side, based on an open source graph view library for Android. We recorded the bluetooth data into a SQLite database for later reviewing and analysing the data. Implemented export and import functionality so that data in csv format can be loaded on other devices or other applications, allowing us to prototype our analysis on PCs and import generated data for testing.
We implemented a questionnaire form that gathers user data for calculating users risk of sleep apnea, to be combined with the recording analysis to help with diagnosis. The diagnosis consists of showing the user how many apnea events take place in a given recording.

When using Oxylyzer it should be noted that it does not take into account patients pre-existing conditions; we are assuming patients have no comorbidity as there can be many variables responsible for inconsistencies in oxygen saturation and heart rate.
Oxylyzer primarily uses the oxygen saturation to determine possible apnea

events. It also incorporates four questionnaires for clinical testing which patients can take on their own to help determine their risk of having sleep apnea.

Pre-Test Checklist

1. Ensure user has not taken sedatives prior to testing sleep meds, alcohol, caffeine etc.

2. Sleep time starts at lights out.

3. Pulse oximeter needs to be placed on index finger / not thumb.

4. Remove nail polish/artificial nails, wash hands.

5. Ensure your hands are not cold [5].

Sleep Apnea Checklist

The sleep apnea checklist consists of a series of clinical surveys in order to gage the patients current state.

1. STOP-BANG (severity check: high/low risk) [6]

Modifications:

2. Epworth Sleepiness Scale (check: 9 or more) [7]

3. Berlin Sleep Questionnaire (severity check: high/low risk) [8]

4. Snore Score (check: if at least one is answered yes) [9]

5. Gender (check: Male most likely)

6. Age (check: 50 more likely)

7. BMI (check: obese, 30 kg/m2 more likely)

8. Neck circumference (check: F: ¿16, M: ¿17) [18]

9. AHI Score determined by analysis [19]

Classifying an Apnea Event

Prerequisites: Ensure user was wearing oximeter for a few minutes prior to recording baseline/apneas to allow

oximeter to calibrate

Baseline oxygen saturation: Oxygen saturation taken before testing should be monitored for

atleast a minute and average it out to obtain baseline [16].

Analysis [17]:

Oxygen saturation is less than, or equal to, 3% below baseline. The start of the apnea.Saturation keeps dropping, when it starts increasing. The end of the apnea. Total apnea time needs to be greater than, or equal to, 10s.

If all the checks pass, add to the total number of apneas recorded for the current hour.

Night Report:

Total sleep time

AHI score (based off of recorded apneas)

Percentage of time spent with oxygen levels below 90%

Lowest hourly average oxygen level and when

Lowest and highest bpm and when

Average oxygen saturation and bpm

Sleep Apnea Analysis Report:

Combine clinical score with AHI to assess risk (user score/4) 4: questionnaires, one or more questionnaires use the remaining 4 variables (age/gender/bmi/neck) already incorporated.

Would be best to combine/average at least 3 nights of data.

Ultimately all the information gathered from the night will be able to be send to the patients physician who would infer their own conclusions from the data provided.

6 Contributions

Individual Contribution

Our team started out with pre-defined roles, however as the semester progressed members ended up shifting positions and crossing over from analysis to development, but such changes are not uncommon in group projects and so we managed to put together Oxylyzer in the following way.

Our individual contributions are as follows:

Fedora Furtado Research, Application Content and Documentation: Researched into sleep apnea, its diagnosis and treatment to see how a mobile application could automate part of the diagnosis.

Michael Zhang - Andriod mobile application Development: Real time and history graph optimization, and apnea event identification and indication.

During the project, Akshay worked on the code for the android application: specifically involving the questionnaires, the settings and other parts. Akshay also helped with the design of the presentation.

The role Dylan played in designing the application consisted of mainly making pages for profile creation and questionnaires. As well Dylan helped design the page for the report which used data from both of these. Aside from this Dylan wrote the code to calculate basic things such as BMI and the questionnaire results. Other than the app development; Dylan contributed by making the power point presentation.

7 Further Application Development

Given more time, to incorporate more ways to help diagnose patients with sleep apnea Oxylyzer would be improved with the following additional features. To better score apnea events, we would record snoring and synchronize sounds with suspected apnea events. Since oxygen saturation is affected by simple movements, checking the apnea event against lack of sound during that period of time, would further increase our probability of successfully scoring apneas. Use of the mobile phones accelerometer could also counteract any movement observed, thereby further ruling out false positives. As per our research, people who were already diagnosed with sleep apnea were using pulse oximeters to check their improvement against the pressure of their CPAP device [20]. People found it problematic to set the perfect titration level and if we could incorporate a correlated pressure

and oxygen saturation tracking program to tell the user whether their CPAP was at its most effective rate or not, it would be an additional feature catering to, and helping, people who were already diagnosed.

8 Conclusions and Discussions

Creating an application to aid in diagnosis has shown our team how tedious it can be to develop and incorporate meaningful software in a medical domain. Further development of this application would be quite helpful seeing as how there is a very realistic struggle in obtaining polysomnogram appointments from labs which are not common in hospitals. As mentioned, sleep apnea untreated can lead to multiple issues, and a large number of the population are unaware of having it. If there were more awareness on the viability of overnight pulse oximetry perhaps a standardized analysis of overnight oximetry could be established to help streamline diagnosis. This could lead the way for more applications such as Oxylyzer to satisfy the demand for a simplified version of the diagnosis procedure while producing relevant conclusions.

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