OxiMUter: Android Application to Measure Blood-Oxygen Level

Paul E. Kaefer[1], Mohammad Adibuzzaman[2], Dan Thomas[2], Mohammad Balfas[2], Xiao Zang[3], Richard Love[4], Sheikh Iqbal Ahamed[2]

[1]Department of Electrical and Computer Engineering, Marquette University, Milwaukee, WI, USA
[2]Department of Math, Statistics and Computer Science, Marquette University, Milwaukee, WI, USA
[3]Department of Biomedical Engineering, Marquette University, Milwaukee, WI, USA
[4]International Breast Cancer Research Foundation, Madison, WI, USA

Abstract— **We present an easy-to-use application for Android mobile phones to measure saturation of peripheral oxygen and the evaluation of this application. This application would provide a non-invasive method of measuring the oxygen saturation of a user's blood. The application can be used for remote monitoring of patients and would provide critical information to the physicians. It also enables them to measure this health parameter without having to buy a potentially expensive pulse oximeter device. The application uses an algorithm developed in previous work. A 30 second video of a user's fingertip is recorded. The frames from this video are extracted and analyzed in order to calculate the pulse oximeter. We show that our application works to measure oxygen saturation in a user's blood using an Android phone with a camera with an error rate less than 2%.**

Keywords: Non-invasive health monitoring, video processing, health parameters.

I. Introduction

The human body requires a certain level of oxygen in order to function properly. Hypoxemia is the term for a low blood-oxygen level. This can cause symptoms from shortness of breath to more severe problems, as bodily organs do not get the oxygen that they need [1]. In order to measure the level of saturation of oxygen in a person's blood, a special-purpose device called a pulse oximeter that clips onto a finger has typically been used in hospital settings such as emergency rooms, post-operative care, or intensive care units. This device has not been extensively used for remote monitoring of patients because of their lack of connectivity, personalization, and storage capability.

Adibuzzaman [2] developed an algorithm that can model features of a video file of a person's fingertip to measure oxygen saturation. The algorithm extracts individual frames from the video, and use the color content of these frames in order to detect oxygen saturation in the blood. This algorithm requires a computer running MATLAB [3]. Zensorium's Tinke application [4] and The Phone Oximeter [5] are two apps that run on iPhones, but require an external oximeter device to function. Bluetooth Pulse Oximeter [6] is an Android application that also requires an external device to take measurements.

Instant Heart Rate [7] is an Android application that uses a video of the tip of a user's index finger in order to determine heart rate. While measuring heart rate is not in the scope of this paper, the technique used by this application closely matches the strategy used in our application.

Our application aims to have the user record a 20-30 second long video of the fingertip with the camera of a mobile phone and the flash light of the camera 'ON'. The application will then process the video. It will extract individual slices of the video file or "frames." By determining the average color values from each of these frames, it will be able to track the changes over time. Given data from 20-30 seconds of video, the app will calculate a measurement that should accurately reflect the user's blood oxygen level. This application is programmed for Android mobile phones, due to their widespread use and availability, as well as the ease with which developers can create Android apps.

This work contributes to the fields of mobile web development, healthcare monitoring, and mobile healthcare availability. By creating a simple application that doesn't require complex medical understanding to use, we enable anybody to be able to monitor their blood-oxygen level at the click of a button.

The rest of this paper is organized as follows. In the Motivation section, reasons behind working on this project will be described. The related works and the system characteristics will be explained in the next two sections. Our solution will be described, along with design details. The performance of the system will be presented in the results section, followed by a discussion section which focuses on the strengths and weaknesses of our system as well as the broader impact of this work. Finally, we make suggestions for future work in the conclusion section.

II. Motivation

The team was inspired by the widespread and increasing use of mobile applications to create an application that would be useful for everyone and can impact more peoples' lives than the current pulse oximeter devices can. This application could be used in developing countries with lower levels of availability of healthcare resources and where mode of transportation is hazardous and often not safe for a critically ill patient. Many people already have phones, so this would enable them to not need an extra device in order to measure their blood-oxygen level.

Consider a scenario where a user has to travel half an hour or more in order to reach a doctor. It is not feasible that they make this trip frequently, when the doctor simply wants to monitor various aspects of the individual's health. This app will enable anybody to make an oxygen saturation measurement, without having to invest in a special oximeter device. Similar apps can enable users to take more and more measurements by themselves, without requiring the assistance of a doctor or separate device.

In some cases, people have limited access to a doctor. The doctor may have many more patients than she or he can handle. In addition, the doctor may visit certain towns or villages infrequently. As an individual's blood-oxygen level may change frequently, it is ideal that some other method of monitoring be available.

Cost is a major issue in healthcare. While mobile "smart phones" tend to cost more than the average oximeter device, many people already have a smart phone. This app enables savings on healthcare, so that money can be spent elsewhere.

III. Related Work

As mentioned in the introduction section, there are a number of related works that have been developed.

Adibuzzaman's et al. [2] created an algorithm that can accurately determine blood oxygen level from a video file. The program uses MATLAB to process data from an .mp4 video file. In addition to generating a numeric measurement, it can display graphs over time, and can also calculate heart rate from the video. It is also personalized, which enables individual readings to be much more accurate than using a multi-person model. The disadvantage of their work is that it cannot be run directly on mobile devices which makes it impossible to use where the user do not have a very good data network, and they do not show an extensive performance evaluation. The iPhone Pulse Oximeter [4], The Phone Oximeter [5], and Bluetooth Pulse Oximeter [6] are all applications available to consumers for either iPhones or Android devices. These devices all require a separate oximeter device to be used, as well. This device clips onto a finger-tip, and plugs into the phone. As a result, it has a high potential for accuracy, given the fact that a dedicated oximeter device is taking the measurements. A downside is the fact that the external device needs to be purchased. These can cost around $100, and many are capable of running without the need for a mobile device.

Instant Heart Rate [7] is an Android-based application that can quickly measure a user's pulse in beats per minute. It uses video rather than an external device. The nature of the algorithm that processes the video is unclear, as the programmers have not released their source code. However it is likely that the application uses color from video files in order to generate a measurement. While it does not measure the oxygen saturation, it is similar to our application in the context that they use visible light photoplethysmographic properties to calculate the heart rate.

Scully *et al.* [8] also measure vital signs with a finger-tip video image which is an extension of [9]. Ming-Zher et al. [10] used a similar approach of [9] to use facial video images to extract different physiological parameters, namely HR, RR, and hear rate variability (HRV) using a webcam.

IV. System Characteristics

The proposed system aims to be easy to use, and be mobile. The algorithm developed by Adibuzzaman et al. [2] works well, with the downside of being incapable of running on a mobile phone. One solution would be to send a video file to a server running the algorithm, but this approach is not scalable

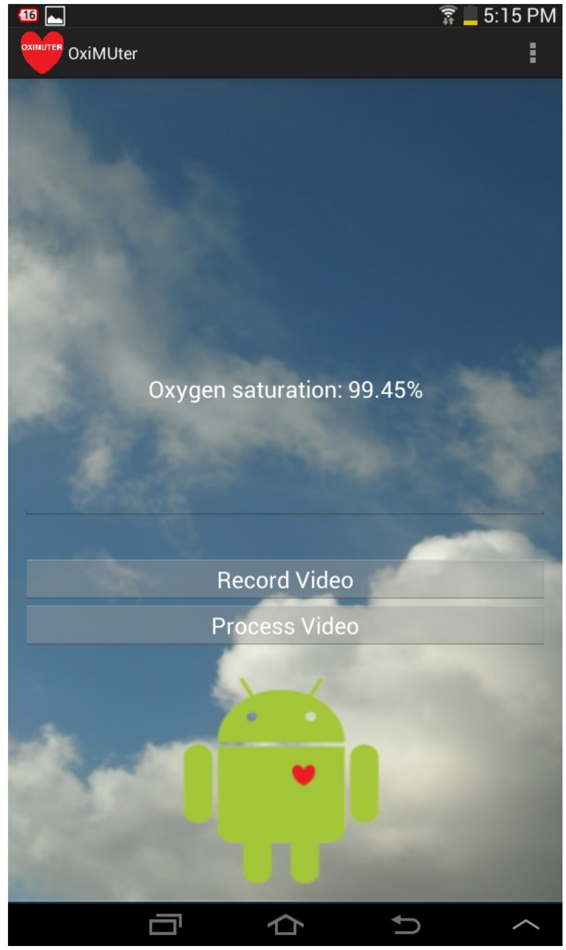

Figure 1. Screenshot of the application showing one measurement of the oxygen saturation.

and would have problems in areas with poor mobile data network.

In order to be usable by everyone, the system should be simple, with not too much information or too many steps. The user is instructed to place their finger on the camera while the video is recorded. The app then handles all the information processing, feature extraction and lets the user know the reading when it has finished.

The application needs to know where the video file has been saved on the system, in order to access it for the video processing. A control has been incorporated to not begin processing if no video file is available.

Once a video file has been recorded and saved to the device, the processing can begin. Frames are extracted from the video. The amount of red color in each frame is then determined and stored in an array. This array is passed to a data processor, which determines the extrema, or minima and maxima, of the time series data. This data may then be fed through an algorithm developed by Adibuzzaman et al. [2], which would calculate a value, termed device saturation parameter (Device SP). The JAMA package is used, since Java does not have the same built-in linear algebra functionality as MATLAB [11].

It is important to note here that the camera on a mobile phone is capable of detecting changes that are difficult or impossible for the human eye to detect. Hence, the video processing will show a change in red color over time that is too subtle for a human to see. This change is what helps determine blood-oxygen level. As blood goes out to the body with oxygen, and returns to the heart for more, that oxygen level, and hence the color of the blood carrying it, decreases and increases.

The system generates a reading based on the data acquired and displays it to the user. Ideally, the system will have personalized data for each individual, as it has been shown that a personal algorithm is much more accurate than an equation that has been trained on readings for multiple people [2].

V. Our Approach

Figure 1 shows a screenshot of one reading from the app. The interface is designed to be clean and simple, with the measurement being in the front and center, as it is the most important part. There are two buttons with obvious names. The user is shown a message to record a video first. If they press the "Process Video" button first, the app will redirect them to the video recording function.

The "Process Video" button finds the video file that was recorded. It then runs a loop to extract color values from each of the frames. The data processing routine is then called to determine the value of the measurement. The app is quick to start up, and may be run multiple times in a row.

VI. Design Details

The design of this application is modular. Video recording, video processing, data handling, and the supervisory main activity are separate modules. Within data handling are several separate methods to handle various aspects of the data processing.

The app performs polynomial regression to map readings from the algorithm to actual oxygen saturation parameters. An array of historical readings for each case is required. At this time, a generic array is used. We will discuss further personalizing this array later in the paper.

VII. Results

Table I shows results from our app, as well as an actual oximeter device. Error ranged from less than 1% to about 7.5%, with an average error of 1.46%.

In general, the app was very close to the readings from the actual device. In some cases, the app gave a reading of 100%, which is not correct. This may have been due to the user turning on the flash. If the flash is on and the finger is covering both the flash and the camera, the readings may be off, as the video will look 100% red from the camera and video processing perspective. Figure 3 shows a comparison of the readings from the application (red trace) and the actual oximeter device (blue trace). The lines are close, with some measurement error.

Figure 3 shows a graph of the percent error for the readings shown in Figures 2 and 3. The absolute value of the errors consistently falls under 10%, but it is believed that this accuracy can be improved. This will be discussed later in this paper.

TABLE I. Comparison table for the app with 20 readings

Reading	Pulse Oximeter	OxiMUter App	Error	Percentage Error
1	96	98.74	2.74	2.85
2	98	99.24	1.24	1.27
3	99	99.62	0.62	0.63
4	98	98.95	0.95	0.97
5	97	99.26	2.26	2.33
6	95	100	5	5.26
7	95	100	5	5.26
8	93	100	7	7.53
9	94	100	6	6.38
10	99	99.99	0.99	1.00
11	99	99.45	0.45	0.45
12	99	100	1	1.01
13	99	99.97	0.97	0.98
14	99	99.97	0.97	0.98
15	99	99.95	0.95	0.96
16	98	94.3	-3.7	-3.78
17	99	97.98	-1.02	-1.03
18	98	97.76	-0.24	-0.24
19	99	99.37	0.37	0.37
20	99	96.08	-2.92	-2.95
		Group Statistics		
Min	93	94.3	-3.7	-3.78
Max	99	100	7	7.53
Mean	97.6	99.0315	1.4315	1.51
Median	98.5	99.535	0.97	0.98

VIII. Discussion

The greatest strengths of this system are ease of use, portability, and adaptability to further development.

The application is easy to use. Instructions are clear and presented in an obvious way. There is not much room for a user to misuse the app, assuming they follow the instructions.

The app is very portable. Users can carry it along with them in their pocket on a device that they probably already have. It will work on a range of mobile devices, assuming they

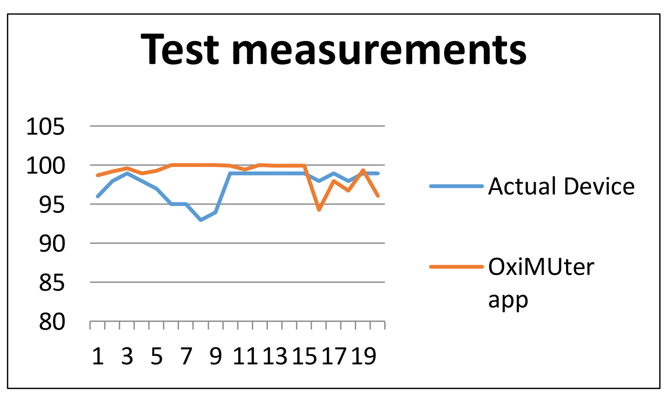

Figure 2. Comparison of pulse oximeter data and the result from our method.

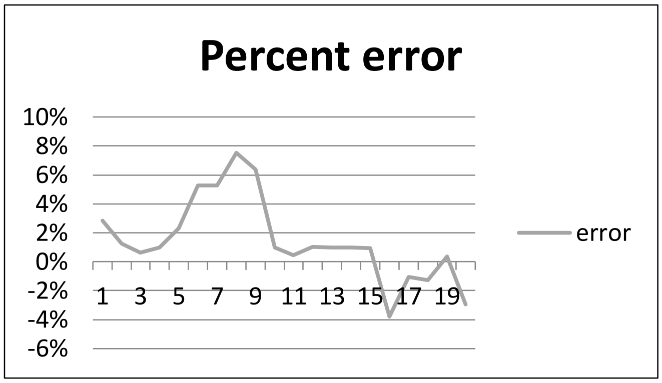

Figure 3. Percentage of error for the readings in Table I.

run Android. It has not been tested on every version of Android available, but it is functional on a range of versions. It is not usable on iOS or Windows Phone, but that may be an opportunity for future development.

Weaknesses include the fact that the user needs to have an Android device with a camera in order to run. These devices may not be as widely available in developing countries.

Another weakness is the fact that the current program is not personalized for individual users. The algorithm that currently runs will be the same no matter who runs it. The videos will produce different results, but it would be more accurate if they were personalized as opposed to not.

As stated in the introduction, this app contributes to the areas of mobile development and mobile healthcare. By taking a look at a problem that hasn't been done in this way before, the project expands the field of mobile app development. Through enabling people to monitor their own health statistics, this app helps advance the field of mobile healthcare.

This application has accomplished its goal of using only video data to generate a measurement of the oxygen saturation of a user's blood. It has been tested to have errors of less than 10%, which is very good.

The "Suggestions for Future Work" section below discusses some improvements that may be done to the application.

IX. Conclusion

While our application works fairly well, there are a number of things that could be improved in future versions. One would be improved accuracy of the algorithm. Adibuzzaman *et al.* [2] show that a personalized equation for each user works much better than a general equation. Our app does not take this into account. It would be more accurate if several readings could be taken using the app, and several readings with an actual oximeter device. The app could then be slightly modified to use this data to map measurements from the video to measurements with an actual device. This would enable more accuracy.

The speed of the app may also be able to be improved. As it currently stands, it takes 20-30 seconds for all processing to occur. This may not be an issue, but it may be frustrating for users to have to wait that long, when a dedicated oximeter device is much faster. Future work can look into improving the performance of our algorithms or alternative methods to achieve the same result.

This app may be optimized for different versions of Android, as well as other available mobile operating systems. As of right now, it will work on Android only, and has not been tested on many previous versions.

This project could also be easily modified to also measure heart rate of the user. It may be beneficial to incorporate the ability to store and recall readings, as well as an option to show some kind of table or graph.

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