Live ECG Readings using Google Glass in Emergency Situations

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Abstract— **Most sudden cardiac problems require rapid treatment to preserve life. In this regard, electrocardiograms (ECG) shown on vital parameter monitoring systems help medical staff to detect problems. In some situations, such monitoring systems may display information in a less than convenient way for medical staff. For example, vital parameters are displayed on large screens outside the field of view of a surgeon during cardiac surgery. This may lead to losing time and to mistakes when problems occur during cardiac operations.**

In this paper we present a novel approach to display vital parameters such as the second derivative of the ECG rhythm and heart rate close to the field of view of a surgeon using Google Glass. As a preliminary assessment, we run an experimental study to verify the possibility for medical staff to identify abnormal ECG rhythms from Google Glass. This study compares 6 ECG rhythms readings from a 13.3 inch laptop screen and from the prism of Google Glass. Seven medical residents in internal medicine participated in the study. The preliminary results show that there is no difference between identifying these 6 ECG rhythms from the laptop screen versus Google Glass. Both allow close to perfect identification of the 6 common ECG rhythms. This shows the potential of connected glasses such as Google Glass to be useful in selected medical applications.

I. INTRODUCTION

Cardiac surgery requires precision and focus. During surgery, the surgeon needs to perform the required operation while insuring that the patient remains stable throughout the procedure. Currently, vital parameters including electrocardiogram (ECG) are displayed on large screens placed outside the field of view of the surgeon when he/she focuses on the operation. In the case of problems, he/she has to look away from the operation to assess the problem and decide what solution is needed. Later, he/she has to refocus on the operation. This situation may lead to medical errors and lost time solving problems.

Connected glasses such as Google Glass have the potential to improve the current situation by allowing the surgeon to always see vital parameters' changes on a prism located close to his/her field of view. Google Glass is certainly the most well–known kind of connected glasses currently available on the market. As illustrated in Fig. 1, it features a camera taking photos at a resolution of 5 MPixels and recording video in 720p, a prism acting as a heads–up display in front of the right eye, a touchpad on the right side of the frame, as well as speakers and a microphone. As an Android device, Google Glass is able to connect to the Internet through Wi–Fi or Bluetooth, understands spoken commands and can read text to a user via earplugs. Freeing the hands of users, connected glasses allow the development of new health applications that can ease the work of medical employees. Some research papers demonstrating the interest of connected glasses for medical applications have already been published [1], [2], [3], [4]. For instance, an exploratory study looked at the limitations of the device during 4 weeks of testing in a hospital [2]. Voice recognition as well as latency, lag time and visual quality of local and transatlantic videoconferencing were tested. The findings demonstrated that Google Glass could be useful in various medical tasks.

However other studies have shown limitations that discourage the use of Google Glass in medical applications [3], [4]. Researchers have shown that using Google Glass for taking pictures during forensic examination yielded worse results and was more time–consuming than the standard method which uses a DSLR camera [3]. Other researchers tried to use Google Glass to read static images of ECG rhythms [4]. In their study, they selected 10 abnormal 12 lead ECG rhythms needing urgent attention from medical staff. The 10 selected ECG rhythms were either shown on paper (the standard way) or a photo of each 12 lead ECG rhythm was taken to be displayed on the Google Glass prism and on an iPhone 5 4.00 inch display. Twelve cardiologists were asked to identify key ECG features present in each of the 10 ECG rhythms. Each correct key feature identified received 1 point. As a result of the study, they found that reading ECG rhythms on Google Glass was significantly worse than reading on a 4.00 inch iPhone 5 or directly on paper. Furthermore, the majority of participating cardiologists were displeased with the quality of the photo of 12 lead ECG rhythms when identifying ECG rhythms on Google Glass. In conclusion, they stated that the main issue with reading ECG rhythms on Google Glass was due to the low quality of the photo.

Despite the difficulties highlighted in this study, we believe that Google Glass can be a useful tool to read ECG rhythms if another approach is taken. Instead of using static photos of 12 lead ECG rhythms, we connected Google Glass to a live monitoring system (ARGUS Pro LifeCare 2, Schiller AG, Baar, Switzerland) (APLC2). The APLC2 sends numerical values describing the ECG in addition to other values describing auxiliary vital parameters. On Google Glass, we developed an application that plots the ECG rhythm from the received numerical values on the upper half of the display. To accommodate the size of the screen projected on Google Glass, only the second derivative of the ECG rhythm is displayed instead of the 12 different leads. Due to its alignment with regards to the cardiac muscle, the second derivative shows the main abnormalities of the main

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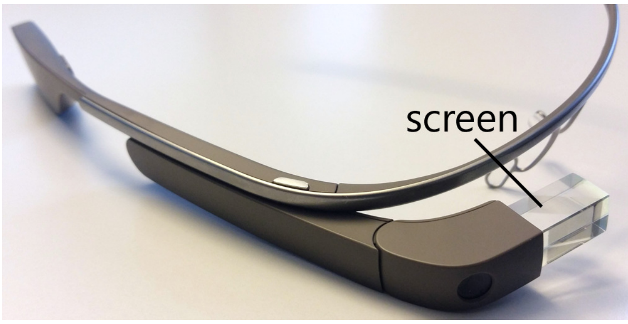


Fig. 1: The Google Glass device and the screen where the ECG is displayed.

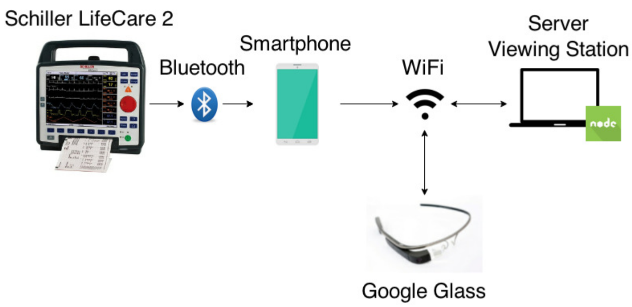
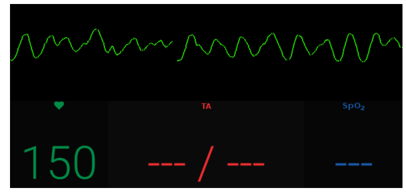
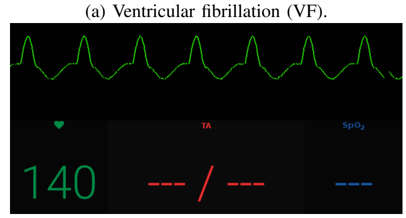


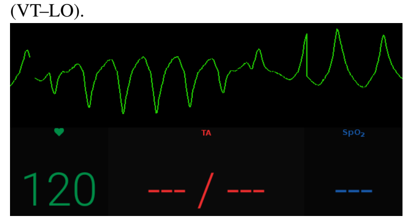
Fig. 2: The testing framework.



(a) Ventricular fibrillation (VF).



(b) Ventricular tachycardia, Wide QRS. Rate 140. (VT–LO).



(c) Torsades de Pointes. Fluctuating QRS axis. (T de P).

Fig. 3: Three ECG rhythms displayed on Google Glass.

ECG rhythms. In order to investigate whether this approach could be of interest in real medical settings, we conducted an experimental study involving medical residents in internal medicine. All participating residents had experience working in an emergency department.

II. METHODS

A. Subjects

Seven medical residents (1 female and 6 male, aged between 27 and 31 years) in internal medicine at Hôpital Fribourgeois (HFR), Fribourg, Switzerland participated in the study. Ranging from 1 to 5 years of medical residency, they all had prior knowledge about ECG readings and the different types of ECG displaying normal and abnormal rhythms. In addition, none of the subjects had prior experience of any kind with Google Glass in professional or personal settings. They were not paid for their participation.

B. Testing Framework

To carry out the study, we modified an existing framework that allows communication between paramedics and an emergency physician located at the hospital and sending information to/from a remote point of care [5]. This framework uses different devices. In this framework, an ARGUS Pro LifeCare 2 (Schiller AG, Baar, Switzerland) (APLC2) was used to monitor 4 vital parameters: (1) second derivative of the ECG trace; (2) heart rate; (3) non–invasive or invasive blood pressure, and (4) oxygen saturation (SpO_2). As illustrated in Fig. 2, the parameters are sent as binary signals over Bluetooth to an Android smartphone (Samsung Galaxy S5, Samsung, South Korea). This smartphone acts as a hub that runs an Android application converting binary signals received from the APLC2 into numerical values and sending these values over a closed wireless network to a local Node.js server running on a laptop (Satellite Z30–A, Toshiba, Tokyo, Japan) using the WebSocket protocol. Google Glass connects to the server to receive the values from the APLC2. As displayed in Fig. 3 and Fig. 4, Google Glass displays the second derivative of the ECG rhythm in green using OpenGL on top of three numerical parameters (heart rate, non invasive blood pressure and SpO_2). In this experiment, only the heart rate is actually displayed as an available numerical value.

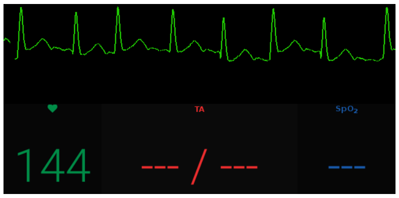
C. ECG Rhythms

To test the ability of Google Glass to be used during medical surgery, we simulate 6 different common ECG rhythms that need urgent attention from medical staff [6] using the CS1201 code simulator (Symbio Corporation, OR, USA):

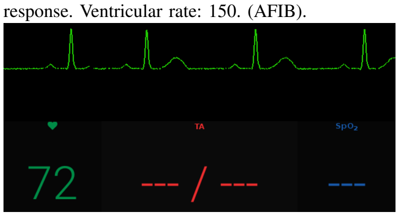
1) Ventricular fibrillation (VF) (Fig. 3a).
2) Ventricular tachycardia, Wide QRS. Rate 140. (VT–LO) (Fig. 3b).
3) Torsades de Pointes. Fluctuating QRS axis. (T de P) (Fig. 3c).
4) Atrial fibrillation with rapid, varying ventricular response. Ventricular rate: 150. (AFIB) (Fig. 4a).
5) Normal sinus rhythm. Rate: 72. (NSR) (Fig. 4b).
6) Sinus bradycardia with inferior ST elevation. Rate: 40 (SBRDY) (Fig. 4c).

D. Procedure

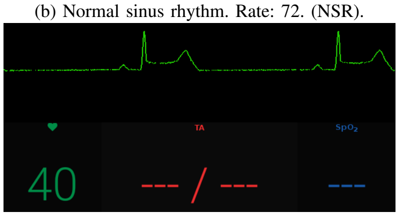
Before the experiment, each subject signed an informative and consent form explaining the general procedure of the



(a) Atrial fibrillation with rapid, varying ventricular response. Ventricular rate: 150. (AFIB).

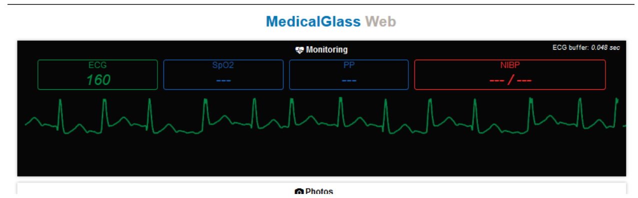


(b) Normal sinus rhythm. Rate: 72. (NSR).

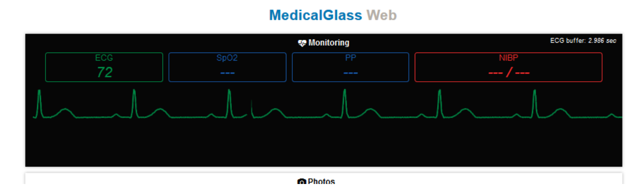


(c) Sinus bradycardia with inferior ST elevation.

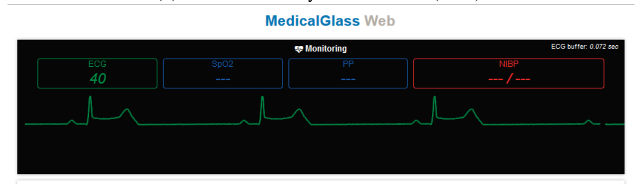
Fig. 4: Three additional ECG rhythms displayed on Google Glass.



(a) Atrial fibrillation with rapid, varying ventricular response. Ventricular rate: 150. (AFIB).



(b) Normal sinus rhythm. Rate: 72. (NSR).



(c) Sinus bradycardia with inferior ST elevation.

Fig. 5: Three ECG rhythms displayed on the laptop screen.

experiment and releasing the right to use their data anonymously. Each subject had to participate in the two following testing conditions:

1) Reading ECG second derivative and heart rate directly on a webpage displayed on a monitor screen of 13.3 inches (1366x768px) as depicted in Fig. 5 (Monitor condition).
2) Reading ECG second derivative and heart rate directly on Google Glass as illustrated in Fig. 3 and 4 (Google Glass condition).

For each condition, we created a practice session of 5 trials allowing the subject to become familiar with the testing conditions and a testing session of 30 trials (5 repetitions of the chosen 6 ECG rhythms). The practice session took place prior to the testing session. A trial consisted of 5 seconds of Asystole (flat line) followed by a maximum of 20 seconds of one of the 6 different common ECG rhythms that need urgent care, described in subsection II-B (ECG Rhythms). The task of the subject was to identify as quickly as possible the ECG rhythm shown after the asystole. As soon as the subject gave an answer the next trial was started. All trials were randomized in both practice and testing sessions. The testing session lasted less than 20 min in each condition (Monitor and Google Glass). At the end of the experiment, we asked the subjects to give feedback on the ease of reading ECG rhythms on Google Glass as well as the potential fatigue induced by the readings on Google Glass.

E. Data Analysis

All experimental recordings were used in the data analysis. Outcomes of both the Monitor and Google Glass condition

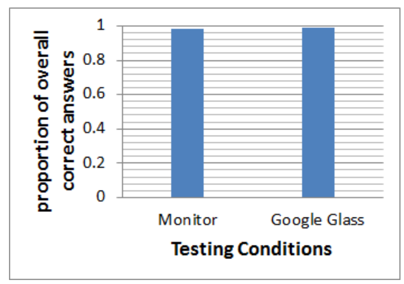


Fig. 6: Overall results of both testing condition showing 98.5% and 99.0% of correct answers for Monitor and Google conditions, respectively.

follow a binomial distribution. Therefore, we used the following equation to calculate the test statistic [7]:

$$z = \frac{\widehat{p}_1 - \widehat{p}_2}{\sqrt{\widehat{p}(1-\widehat{p})(\frac{1}{n_1} + \frac{1}{n_2})}}, \quad (1)$$

where

$$\widehat{p} = \frac{(n_1\widehat{p}_1 + n_2\widehat{p}_2)}{(n_1 + n_2)}, \quad (2)$$

where $\widehat{p}_1$ and $\widehat{p}_2$ represent the proportion of success in the Monitor and Google Glass condition, respectively. n_1 and n_2 are the sample sizes, respectively in the Monitor and Google Glass condition.

As we are interested in testing the hypothesis at the 95% confidence level, we compare the test statistic against the critical region value $z_{a/2} = 1.96$. If $z > z_{a/2}$, we can reject the null hypothesis. To get the precise p–value, we perform a Fisher's Exact Test [7].

III. RESULTS

With a total of 210 trials in both testing conditions, Fig. 6 shows that both testing conditions have a very high proportion of correct answers. The Monitor condition had a score of 207/210 (98.5%) whereas the Google Glass condition had a score of 208/210 (99.0%). After discussing with the subjects, the failed trials appeared to be due to inattention during the experiment. Based on this observation and on the high score in both testing conditions, none of the selected ECG rhythms was noticeably more difficult to identify.

Using Eq. 1, we computed the statistic test with the following parameters: $\widehat{p}_1 = 0.985$, $\widehat{p}_2 = 0.990$, $n_1 = n_2 = 210$. Using these parameters, z equals to 0.4499 which is lower than 1.96 set as the minimum threshold to reject the null hypothesis stating that both testing conditions are equal. In addition, Fisher's Exact Test displays a p–value of 0.814 well above the 0.05 threshold. This shows that there is no significant difference between the two testing conditions.

IV. DISCUSSIONS

The results from this experiment show that both testing conditions are statistically indistinguishable. With close to perfect scores, subjects were able to identify abnormal ECG rhythms regardless of whether it was shown on a laptop screen or directly on Google Glass. This observation is in contrast with the results observed by Jeroudis *et al.* [4]. In their study, they acquired a photo of 12 lead ECG rhythms printed on paper. While this approach replicates the standard way ECG rhythms are currently screened in hospitals, it does not fit the current screen of Google Glass due its relative small size and resolution. Using only one derivative for display in the Google Glass appears to solve this problem. A possible explanation to clarify the difference of results between the current study and the study using static images of ECG rhythms lies in human visual perception. Researchers have shown that unexpected changes of direction of objects in motion attract attention [8]. In their study, they demonstrated that subjects were disrupted when moving objects unexpectedly changed directions in the background while performing a tracking task on other objects. The same subjects were not disrupted while performing the same task when moving objects followed a logical path. Based on this demonstration, using live ECG rhythms during rapid diagnosis could have the advantage of drawing attention on unexpected changes of live rhythm compared to printed ECG rhythms. It is also a good starting point for a larger study using real ECG rhythms in a clinical scenario. As long as the ECG rhythm is stable, surgeons should have no difficulty to focus on his/her operation. As soon as the ECG rhythm becomes unstable, his/her attention is attracted by the changes allowing him/her to take relevant actions.

However, it is true that hiding ECG derivatives may render diagnosis of finer or smaller abnormalities more difficult or even impossible. In this regard, this study has been designed to only focus on emergency situations where medical staff has limited time to react and can spend little time reading ECG rhythms. For other situations, we agree with the conclusion made by Jeroudis *et al.* that fine abnormalities of ECG rhythms are easier to diagnose on paper.

At the end of the experiment, subjects reported some fatigue after reading ECG rhythms on Google Glass due to the length of time they had to focus on the small screen. However, all subjects reported that there was the same small low level of difficulty to identify ECG rhythms from a laptop's screen and Google Glass' screen. This shows that it is possible to identify ECG rhythms on Google Glass if we accommodate its limitations. This accommodation of physical limitation can be extended to the development of other applications and on other new devices.

Nevertheless, connected glasses such as Google Glass are still under development and applications running on them must be designed with care. However, novel designs of use cases attempting to solve medical related issues appear to be quite successful [1], [2], [5].

V. CONCLUSION

This paper describes an application developed for Google Glass allowing medical staff to identify abnormal ECG rhythms without losing track of the task they are performing. Non–disruptive display of information in front of a user is the main advantage of using connected glasses such as Google Glass in medical settings. On the one hand, this paper shows a successful preliminary study. However, a study closer to a real–world scenario using real ECG rhythms has to be performed to confirm the usability of such an application in clinical settings. On the other hand, this paper shows the potential of such a device for medical applications if they are carefully designed to help medical staff in concrete situations.

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