An Interactive Tool for the Evaluation of ECG Visualisation Formats

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Abstract

Electrocardiograms are typically printed on graph paper. Based on these recordings clinicians look for changes in the various waveforms when they make a diagnosis. In some cases, however, these changes are not always obvious on the standard printed 12-lead ECG. For this reason researchers have developed different methods for presenting ECG information. This paper reports on the development of an interactive system that supports the display of ECG information in a number of differing formats. The system is currently configured to display ECGs in either the 12 lead ECG, Body Surface Potential Maps or ST Map format. The system has been designed to provide basic ECG viewing functionality and it is planned that it will be used in the evaluation of ECG interpretation skills in students undergoing training in ECG interpretation. Future work will be directed towards making this system compatible with mobile computing platforms, subsequently allowing access even when the students are not near a desktop computer.

1. Introduction

Electrocardiograms (ECGs) are generally printed on thermal graph paper. This allows the clinician to identify the best treatment for the patient based on changes displayed in the ECG waveforms. Nevertheless, some changes are not always visible on the printed 12-lead ECG [1]. Therefore researchers have developed alternative methods of viewing ECG data.

One such technique is the ST Map [2]. ST mapping, allows the traditional 12-lead ECG, specifically the ST segment to be displayed more clearly. An ST map on the bedside monitor of a patient, would allow clinicians to observe and note any key changes associated with myocardial ischemia [3].

An alternative visualisation format is the Body Surface Potential Map (BSPM). The BSPM has been introduced as a clinical visualisation technique that enhances diagnostic power when compared to the original 12-lead ECG [4]. A BSPM can utilise up to 200 leads to gather information from the entire surface of the patient's torso [5], enabling more data to be collected [6].

This paper reports on the development of an online interactive system that supports the display of 12-Lead ECGs, BSPMs and ST-Maps. Additionally, the system provides a means to evaluate ECG interpretation through the backend timer that records how long a user viewed an image before a diagnosis was made. Although these formats have been available in recent years, there has yet to be a combined online interactive system created which displays these ECG visualisation methods.

2. Background

In a study by G. Alinier *et al.* [7] it is stated that although there has been a rise in the use of technology within healthcare education, there is still scope for improvement. They go on to note specifically, that there are no teaching tools available for clinical measurement assessments. This is applicable in the ECG domain where training and education may be difficult to fully comprehend if students and clinical staff are not able to have 'a hands on' learning approach [7].

The need for educational tools and simulations that allow students and medical staff to achieve a higher level of knowledge within the ECG domain, are something that will be continually required for all those seeking to work within a clinical environment [8]. As reported by Sangkachand *et al.* [4], "If a clinical improvement is easy to use, the likelihood is greater that nurses will adopt it". Therefore, it is deemed to be important to develop a system that allows users complete interactivity whilst at the same time reducing any usability complications.

A similar interactive simulation package for both teaching and researching has been developed by van Dam *et al.* from the Radboud University Medical Center, the Netherlands. The tool is called ECGSIM and is freely available online [9]. ECGSIM allows the user to induce changes within the electrical activity of the myocardium. These changes can be easily observed on the corresponding ECG, as modifications are displayed instantaneously on screen.

Work by Patuwo *et al.* [10] made a comparison between teaching basic electrocardiographic concepts with and without the use of ECGSIM. Thirty-five students from Duke University North Carolina, United

States, were split into two groups. One group used ECGSIM as an aid to ECG interpretation and the other group did not use the software. Students taking part in the study were part of a summer medical course and had no prior experience in ECG readings.

Before the study started, all students were provided with basic details relating to the mechanics of the heart. This was delivered through an oral presentation and a printed hard copy of the delivered material. The students who were not using ECGSIM did not receive any additional training. The students who would be using ECGSIM were given additional instructions on how to use the software. Results indicated that the students who used the ECGSIM software obtained a higher level of accuracy (45.7%) in relation to determining the mean of the QRS axis to within 10 degrees, when compared to students from the second group (21.4%), who calculated without the use of the ECGSIM. Patuwo *et al.* also described how through using the ECGSIM software as an aid to Electrocardiology teaching, it could prove beneficial to students in terms of reading and interpreting ECGs [10].

Online and portable computing applications are becoming further available and more accepted within the clinical domain. Some of these features can be utilised through telemedicine with its broad range of benefits that this type of healthcare has to offer.

Hsieh *et al.* [11] conducted studies that developed a 12-lead ECG telemedicine solution through the introduction of mobile computing [12-15]. The study allowed the cardiologist to have a connection between his/her mobile phone and the hospital database. This offered immediate access to patient records and ECG reports, allowing a direct diagnosis and appropriate courses of action to be taken. This feature is portable, convenient and efficient [11], granting immediate access to patients and their details when the cardiologist is not always nearby.

Additionally, the same technology can be implemented into a portable transmitting device to be used within an ambulance. To enable the clinician to receive the ECG, the paramedic must first record it. This is achieved through the use of Wi-Fi or 3G, where the patient's ECG is transmitted to the local hospital and mobile phone of the clinician in real time. This system provides swift transmission between equipment inside and outside the hospital [11]. The concept being that off-site a clinician may make a pre-hospital diagnosis and therefore shorten the "door-to-balloon" time should treatment in the catheter lab be required.

Developments are continually being made in relation to smartphone based telemedicine systems. New features include allowing ECGs to be viewed and monitored using this technology. As presented by Johannesen, through the ever growing population and the wide range of smartphones available, nurses and paramedics are able to record an ECG and transmit the data to a cardiologist to diagnose the patient [15]. Nevertheless, as stated by Finlay *et al.* who evaluated a similar smartphone application, additional research is still required to help refine development [16]. Thus proving further visualisation techniques and improvements are required in this line of development.

A further issue with BSPMs is the lack of user-friendly visualisation tools [17]. Clinicians need to be able to view and work with the large amounts of data received from the patient's BSPM. Having a visualisation tool could help manage and reduces medical errors, previously associated with handling large volumes of data [18].

In light of this, a 'web based visualisation tool for transforming the 12-lead ECG into a Body Surface Potential Map [5]' has been developed at the University of Ulster. Bond *et al.* described how the overall objective of creating a viewer was to be as 'clinician friendly [17]' as possible. The system was created using Adobe Flash technology, using vector graphics where the ECG could be easily scaled as necessary enabling the clinicians to measure the various waveforms as required [5]. The system was developed within a web-browser, reducing the need for installing any software or completing any updates. An extra feature added to the system permitted the user to download and print the BSPM as a scalar vector graphic (SVG) [5].

An evaluation of this system has been carried out at the 2010 Computing in Cardiology conference where 7 male delegates took part. The results demonstrated that when each delegate was asked to 'think-aloud,' all participants agreed that a BSPM visualisation tool was required to perform further studies and research into the ECG domain. Similarly, 6 of the 7 participants stated that they thought it would be useful in the education and teaching of ECGs, in addition to recommending the viewer to other potential users [17].

This paper reports on the development of an online interactive system that supports the display of ECG information in a number of differing formats. The system was developed using free, open source coding languages; including PHP, MySQL and JavaScript. These languages eliminate the need for the end user to download any additional programs or software. The open source model has been used for similar medical imaging software, including OsiriX [19] – a medical viewer designed specifically for displaying radiology images.

3.   Methodology

The system was designed to run as a web-based platform as this offers the best method of data capture for a large group of users simultaneously. Through using web based technologies, the system does not require any additional software to be purchased and installed. Through an internet connection, the system is available

24/7 and is accessible within the browsers Chrome, Firefox and Safari. It can run on any platform including a Windows PC and an Apple Mac.

The system was developed using Abode Dreamweaver and written in PHP, HTML and JavaScript. In order to allow multiple users to log in and write comments, PHP session variables were created at the start of the index page. This allows the user to select and comment on each image and subsequently submit details to a backend MySQL database. PHP offers a connection between the front-end system (visible to the user) and the backend database where user selections are stored. HTML was used for the design and layout of the front end of the system. This includes the colour scheme, initial login screen and the series of drop down menus. JavaScript was used to implement the 'no right click available' function in addition to populating the various drop down menus according to user selections.

In order to help create the structure of this system, a component diagram was designed identifying key areas of user interactivity. These were identified as being an authentication manager and a file visualisation manager. These features are accessible through the creation of a graphical user interface. The authentication manager handles both user details and stored details held within the database; whilst the file visualisation manager handles displaying the selected files based on the user inputs. The relationship between these two components is highlighted in Figure 1.
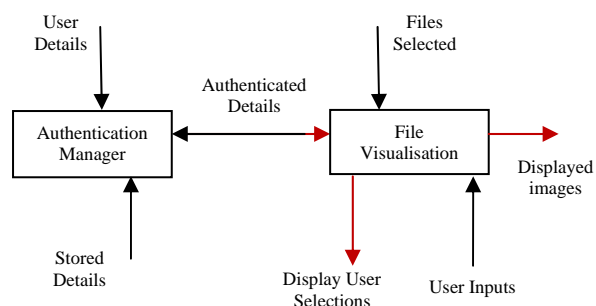
Figure 1: The main components of the ECG visualisation system. The black arrows indicate information being inputted to the system, and the red arrows indicate information that is being outputted by the system.

The system was designed to provide basic ECG viewing functionality of various types of ECG formats. At present, the system is configured to display 3 formats, 12-Lead ECG, BSPM and ST-Map. Nevertheless should additional ECG formats be required, this can be easily achieved and therefore not limited to these initial selections. These 3 formats were selected because they display the same information, illustrated in a slightly

different way. The 12-lead ECG is the traditional method of viewing ST-elevations (STEMIs) and non ST-Elevations (non-STEMIs). The ST-map was designed to highlight the various leads affected and the BSPM offers a different colour-coded approach to interpretation.

During development, the system was designed using 4 separate areas. These are left aligned as the eye typically starts reading a page from left to right. The first area is the heading section, the second is the selection option, the third is where the chosen image is displayed and the fourth is the diagnosis section. Figure 2 illustrates this.
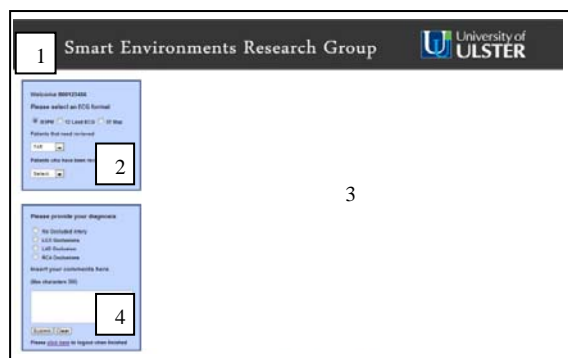
Figure 2: The four sections of the interactive tool. The first number box illustrates the header section of the page, the second box shows were the user will make their selections which in turn is displayed in the area labelled 3. The forth box is where the user will select the diagnosis and give further information in the textbox provided.

Once the user is provided with their credentials they can gain access to the system through the initial log in page. After successfully entered, the user is presented with a main screen similar to Figure 2. Throughout the design phase it was imperative that user interactivity and functionality where always considered. In light of this, the use of jQuery 'tooltips' were included with the intention of adding increased operability to the system. Therefore once the user has chosen which type of ECG format they would like to view, they are presented with two drop down selection boxes. The first illustrates the images still to view, whilst the second shows the images that have already been viewed. Both of these offer a hover style effect reminding the user what each box is designed for.

To allow for future evaluations with students undergoing training in ECG interpretation, it was important that user input/feedback could be entered and stored within a database. For the current use of the system, the user must make their diagnosis from four options; firstly no occluded artery, secondly a left coronary artery (LCX) occlusion, thirdly a left anterior descending (LAD) occlusion and lastly a right coronary

artery (RCA) occlusion. Users are also encouraged to leave further comments within the text box in relation to the clarity of the images or any difficulty/ease of use they had when making their diagnosis.

Once the user data has been submitted, the information is sent and stored within a backend database for future analysis. Within the database 'time taken' which represents in seconds how long each image was displayed on screen is stored. This feature is important when comparing between the sensitivity and specificity between those ECGs that the occluded artery was correctly identified and those that were incorrectly identified. It will be interesting to note if a user spent longer looking at an image whilst providing a false diagnosis or if they spent a relatively short period of time viewing for example all the LAD occlusion images in comparison to the LCX occlusion images.

4.   Future work

Future work would like to see this system compatible with mobile computing platforms. These include tablet devices and handheld computers. This would allow access even when the students are not near a desktop computer. For this to happen, improvements need to be made in relation to the screen size and display, so that none of the quality or information is missing once viewed on a smaller scale.

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