Internet based ST Map Software: A Web Service, a Decision Support System and an Educational Tool

Raymond R Bond[1], Dewar D Finlay[1], Daniel Guldenring[1]

[1] University of Ulster, Jordanstown, Northern Ireland, United Kingdom

Abstract

Introduction: ST segment values are used to assess patients with suspected acute myocardial infarction. Given ST segment changes can be missed in busy clinical environments, researchers have proposed the ST Map as an alternative for depicting ST segment data. Given this approach has shown potential for use within routine clinical practice, we implemented a web based visualization system that could be used to further its acceptance.

Methods: This ST Map software was developed using ActionScript 3.0 and the Adobe Flash IDE. The software parses ST values and draws two ST Maps that represent the horizontal and frontal planes respectively. ST values can be presented as vectors or as polygons.

Conclusions: This tool can potentially be used as a decision support system where a user can input ST values and use the resulting graphic as an adjunct to assist a diagnosis. It can also be used as an educational tool for learning relationships between ST vectors and ischemic regions. Thirdly, the tool can be used as a web service by third party ECG applications and machines.

1. Introduction

The 12-lead electrocardiogram (ECG) is a very useful tool for rapidly and non-invasively assessing if a patient is experiencing an acute myocardial infarction (AMI) [1]. In determining an AMI, a clinician must analyze the ST segments in all 12 leads. If two or more contiguous leads exhibit ST elevation, the clinician can diagnose the patient as experiencing an AMI and can follow up with appropriate reperfusion therapy [2]. However, ST elevation criteria has a low sensitivity ($\approx$50%) for determining AMI [3]. Thus, clinicians are known to consider ST deviation in their diagnosis [4]. ST deviation involves consideration of both ST depression and ST elevation. It has become important for non-cardiology experts (e.g. nurses stationed at a coronary care unit) to recognize ST deviation as displayed on a bedside monitor [5]. Hence, intuitive visualization of ST deviation is imperative. Given the ST segment is a small portion of the ECG complex, other peripheral ECG information can be provisionally removed for determining the presence of ischemic type changes. This reduction in information overload has the potential to facilitate a clearer and focused depiction of ST deviation. As a result, a number of researchers have proposed alternative visualizations of ST segment deviation. Andersen et al. [6] and Philips Healthcare [5] have proposed various versions of what has been called the ST Compass and the ST Map. An ST Map or Compass depicts ST deviation as vectors or as polygons superimposed onto spatial planes (i.e. the frontal and horizontal planes). Given that recent evidence suggests that the ST Map improves the recognition of ST changes [5], we developed a tool to facilitate the visualization of the ST Map in a web browser. We hypothesize that this tool could be used in various ways, i.e. as a web service, a decision support system or as an educational tool.

We also want to point out that aside from the reports in the literature no freely available ST mapping software has been made available for researchers to experiment with.

2. Methods

The ST Map system was developed using ActionScript 3.0 (a programming language for Adobe Flash). The software uses ST values to display two ST Maps to represent the horizontal and frontal planes respectively. Each ST Map consists of 1mm concentric circles, which can be used for reference. The current version of the system has now been made available on the Internet [7]. A basic representation of the system processes have been illustrated in Figure 1 using a flow diagram. With reference to Figure 1, item D1 (or decision 1) infers whether ST microvolt values have been automatically passed into the system. This feature allows the system to function as a web service by implementation of the REST protocol (or representational state transfer). This allows third party computer programs or devices to automatically generate ST Maps. This can be done by appending ST segment values (in the form of GET variables) to the URL. An example of this has been shown Figure 2. If these variables exist, the system parses the values (in P1 or process 1) and proceeds to convert the values to
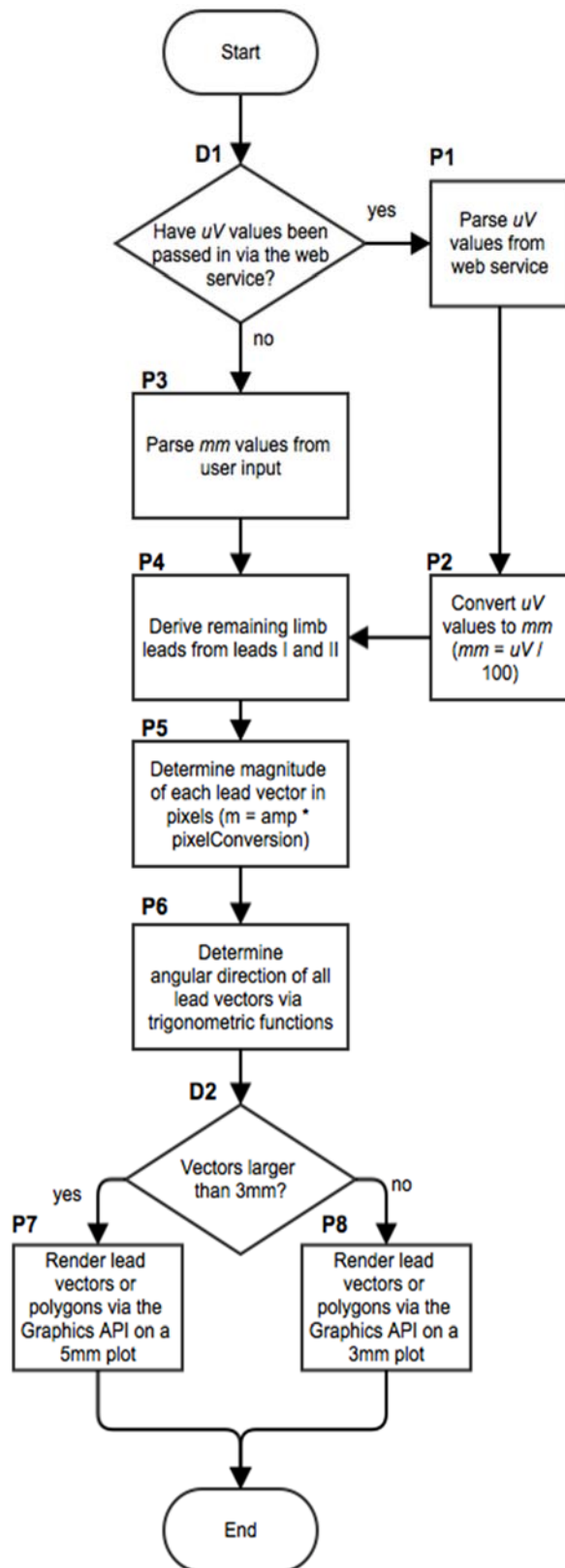
Figure 1. Flow diagram depicting the system architecture of the ST Map software.

millimeters (P2). Otherwise the system parses ST values that have been manually inserted by a given user (P3). In either case, the system in P4 uses the ST values for leads I and II to derive the ST values for the limb leads III, aVR, aVL and aVF.

Subsequently, the magnitude of all 12 vectors are determined in pixels (P5). This is the product of an ST value and a ratio (pixel conversion). Although this is not shown in Figure 1, the ratio is modified depending on whether the vectors are plotted onto a 3mm or a 5mm diagram. Whilst P5 determines the magnitude, P6 determines the angular direction of each vector. For example, if a given ST value for lead aVF is negative, the angular direction for its vector is set to 270° otherwise it is set to 90° on the frontal plane.

All 12 vectors are finally superimposed onto either a 5mm or a 3mm diagram (refer to D2, P7 and P8). This is done using basic trigonometry and the Graphics API. Each vector is drawn from the center of the diagram (i.e. the vector origin representing 0mm) to the terminal point (i.e. the vector end). The terminal of each vector is determined in Cartesian coordinates (pixels). The x coordinate is determined using the following function.

$$f(x,y) = y\left(\cos x \frac{\pi}{180}\right)$$

where x is an angle in degrees and y is ST amplitude value. The function returns the x coordinate, which is the product of the cosine (given an angle in radians) and the ST amplitude value. In a similar way, the y coordinate is determined using the following function.

$$f(x,y) = y\left(\sin x \frac{\pi}{180}\right)$$

where x is an angle in degrees and y is the ST amplitude value. Having determined the complete set of Cartesian coordinates in pixels, the system draws the vectors using the Graphics API. Example ST Maps that have been generated using this system have been shown in Figures 3 and 4.

http://scm.ulster.ac.uk/~scmresearch/ bond/deviate/index.php ? **vone**=*50* & **vtwo**=*92* & **vthree**=*128* & **vfour**=*98* & **vfive**=*68.6* & **vsix**=*-3* & **one**=*-14.5* & **two**= *-22.1* & **name**=John_Smith

Figure 2. A REST web service example where ST values in microvolts are appended to the URL. The web service receives nine variables (vone, vtwo, vthree, vfour, vfive, vsix, one, two and name). The question mark ('?') delimits the URL from the variables and the ampersand ('&') delimits the individual variables. (NOTE: in practice no spaces should exist in the URL string).
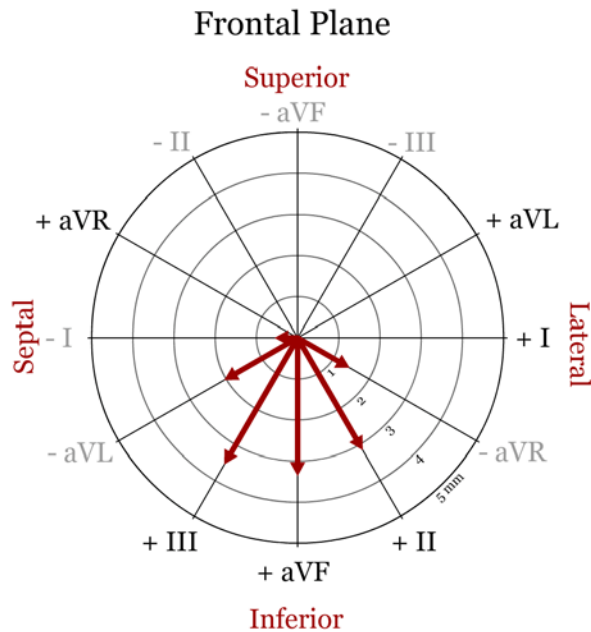
Frontal Plane

Figure 3. ST Map as produced by the system showing the ST vectors for the limb leads on the forntal plane.
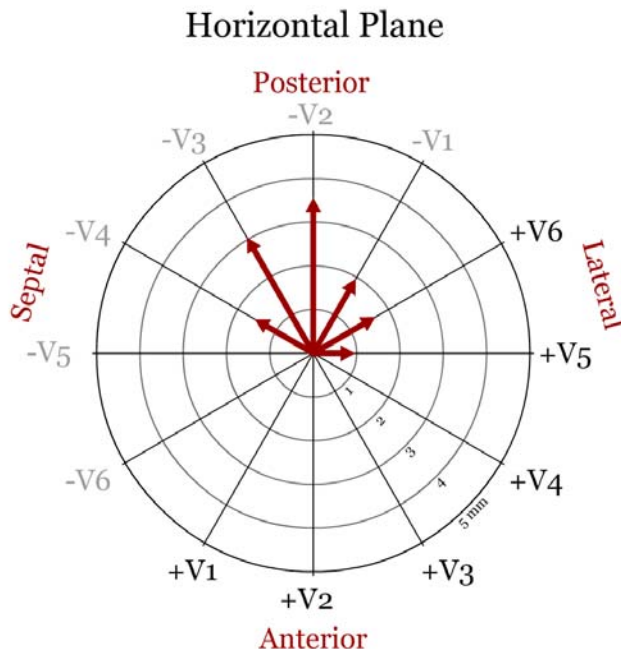

Horizontal Plane

Figure 4. ST Map showing the ST vectors of the precordial leads on the horizontal plane.

3.   Discussion

Accurate and intuitive visualisation of medical signals is extremely important given the myriad of information clinicians are required to analyse in a limited amount of time. The latest technological developments in CPUs, fibre optic broadband and cloud computing allow for improved processing and automated analysis of 'big data' [8]. However, turning data into an intuitive graphical display is a different problem from processing data. And unfortunately no amount processing power can enhance graphic and information design in medicine. Moreover, due to tradition and fear of upsetting standards, medical signals such as the ECG have been visualized in the same format for over a century [9]. Given Johnson et al. [10] predicted that scientific visualisation will be one of the greatest challenges in the 21st century, perhaps the time will come to optimise the display of ECG data for rapid and accurate interpretation (especially for very specific scenarios such as ischemia monitoring). In the case of the ST map, this new simplified method may improve the uptake of ST segment monitoring amongst nurses [5]. However, as presented in a recent review [9], this is only one of many novel ECG visualization techniques.

4.   Conclusion

1. We developed a tool that could be used as a decision support system where a user could input ST values and use the graphical display to assist in making a diagnosis. 2. A tool that could be used as a pedagogic platform for learning the relationship between ST vectors and ischemic regions. 3. A tool that could be used as a web service by third party ECG machines for the automatic creation of ST Maps.

Perhaps the most significant contribution in this project is the public availability of an ST mapping tool that until now has not been made freely available to researchers and educators to experiment with.

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Address for correspondence.

Dr Raymond Bond (rb.bond@ulster.ac.uk),
University of Ulster (UUJ),
Shore Road,
Newtownabbey,
Co. Antrim,
BT370QB