EKGAR: Interactive ECG-Learning with Augmented Reality

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Abstract

Many medical students find it a major challenge to acquire a spatial understanding of the correlation between visual appearances of electrocardiograms (ECG/EKG) and the 3D location of acute myocardial infarctions (AMI) in the heart. We introduce an Augmented Reality (AR) concept (EKGAR) that uses 3D visualizations and a tangible interaction paradigm to enhance medical students' ability to locate AMIs in 3D. Combining vision-based 3D tracking technologies with a playful interaction metaphor, users can search for infarctions by navigating through and slicing open 3D representations of a patient's heart. This constructionist learning approach, makes students obtain an immersive experience when using the EKGAR system. We discuss design reflections, aspects of the technical implementation and user evaluations.

Keywords: Augmented Reality, Learning, Medical Informatics Applications, Medical Technology, Multimedia, Myocardial Infarction, User-Computer Interface.

Introduction

Due to our lifestyle, acute myocardial infarction (AMI) has become one of the most frequent chronic diseases in the western world. Physicians typically identify these chronic diseases using standard 12-lead ECGs, which produce 12 simultaneous 2D graphs in real-time, visualizing the overall physiological condition of the patient's heart [3]. It's the physician's job to select among these graphs and translate the complex visual data-plots into mental 3D images of the heart, and correctly pinpoint the position of a potential AMI.

Emerging technologies are pushing the boundaries for advanced interaction and visualizations methodologies in both learning and complex information spaces. In the medical realm, virtual reality has been the predominant technology [4], but lately we have seen sophisticated applications of AR [9] [6] where the user's perception of the physical world is overlayed with digital information [2] [8], establishing a proprioceptic connection between the virtual and physical world.

With EKGAR, it is our goal to extend traditional ECG teaching with AR learning experiences. Instead of one-way verbal communication between teacher and students we combine ECG reading with AR visualizations and tangible interaction, thereby enhancing medical student's spatial awareness in locating AMIs. We use AR technologies to mediate and create playful and immersive experiences, making the students become more engaged in learning ECG reading [5].

Prototype Design and Implementation

In EKGAR, design goals include ease of use and support for playful experiences without lengthy training and introduction. Consequently the system is designed as a kiosk-like installation that automatically activates and initializes a set of visual data when users approach the system, carrying an RFID-tagged box containing patient case materials. Upon activation, a set of physical blocks with fiducial ARToolkit markers [1] can be attached to the interaction tool. A ceiling mounted camera track each block and project a visual 3D representation of the patient's heart onto a wall-sized display or alternatively in a HMD, as shown in Figure 1.

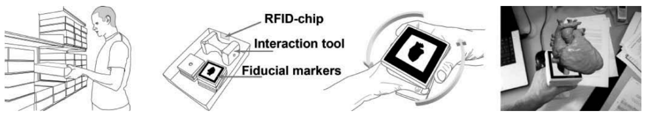

Figure 1 – The concept in EKGAR.

If a specific 3D visualization supplies insufficient data about the patient's condition the users can freely interchange markers to get an alternative view inside/outside the heart or its coronary arteries. Next to the 3D visualization, the users are presented with a live view of the patient's ECG. That way the users can correlates 2D ECG plots with 3D visualizations.

Turning the interaction tool is detected by the camera and the 3D models are aligned accordingly in real-time. Thus the users experience they are holding the virtual heart in their hands. This kind of augmentation provokes alternative ways of interacting with virtual learning objects, and according to [5] this creates immersive and engaging learning experiences.

Technical implementation

We base our EKGAR prototype on DART [7], a comprehensive AR framework, developed as an extension for the Macromedia Director authoring software. DART allows for easy development of complex prototypes Combining Director's strong 3D engine with DART's integrated ARToolkit functionality we use binary image analysis to do precise tracking of user interaction, and display seamless integration of the virtual heart, as shown in Figure 2.

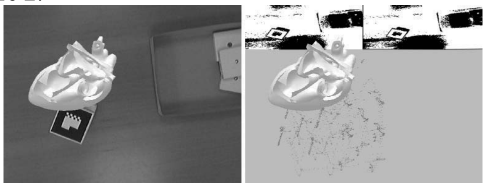

Figure 2 – Early EKGAR prototype and image analysis.

Patient data such as patient history and ECGs are stored in XML databases. To extract and display these data we have implemented a flexible XML-module in Macromedia Flash, which has been integrated in the interface of the EKGAR application, developed in Director.

User Evaluations and Future Work

From day one, we put a strong focus on user-centric development. Prior to the prototype development we conducted numerous qualitative inquiries with medical students in order to map issues and potentials regarding the application design. The same users were included several times during the implementation process to verify and/or correct erroneous aspects of the application functionality. Finally we did several user evaluation of the current prototype to get a verification of its potential benefits in medical education.
In general, the users' responses to the prototype were quite positive, but they also gave us directions towards further development. They pointed our attention to the need of upgrading our 3D models in such a way that the heart's outer walls are not visualized only as shell surfaces but with a volumetric appearance instead. Also, it has come to our attention that we need to enhance our ceiling mounted camera tracking methodology, since the users sometimes find it awkward with a top-view display of their interaction with the virtual learning objects. Currently we are looking into translucent projection displays and tracking of user interaction by means of physical objects with embedded 3-axis accelerometers.

Conclusion

In this short paper we presented an AR interface for ECG learning in medical education. The presented prototype addresses challenges met by many medical students when transforming complex 2D ECG plots to a spatial 3D understanding of the location of a potential AMI.
Compared to the above-mentioned state-of-the-art AR applications for the medical realm, we have contributed with an innovative AR system for learning ECG reading, which has no direct competitors.

To reach a final release candidate various aspects of the application needs to be further developed. This mainly relates to more advanced and accurate 3D tracking technology but also use of alternative displays for visualizing the interactive 3D learning objects.
Finally the system needs to be further validated against a larger population of test users, including medical students as well as cardiologist who are experts in the field of specific cardiovascular diseases.

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