Low-Cost, Take-Home, Beating Heart Simulator for Health-Care Education

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Abstract. Intended for medical students studying the evaluation and diagnosis of heart arrhythmias, the beating heart arrhythmia simulator combines visual, auditory, and tactile stimuli to enhance the student's retention of the subtle differences between various conditions of the heart necessary for diagnosis. Unlike existing heart arrhythmia simulators, our simulator is low cost and easily deployable in the classroom setting. A design consisting of solenoid actuators, a silicon heart model, and a graphical user interface has been developed and prototyped. Future design development and conceptual validation is necessary prior to deployment.

Keywords. simulator, cardiac, arrhythmia, education

Introduction

Memory retention can be enhanced by providing multiple forms of sensory input, such as auditory, visual, and tactile data [1]. Using this premise, we set out to design a heart simulator that supplements didactic and textbook material for beginning or advanced students in the medical field and enable them to cater the learning experience to their own personal learning style at home. Additionally, the kit should have a total part cost limited to approximately $150.00 in order to facilitate widespread classroom distribution.

Prior art in the area of cardiac simulators includes computer models, simulated electrocardiogram (EKG) graphs, and physical beating heart simulators [2,3,4,5]. Much of the previous work focuses on one aspect such as having an advanced computer model. However, this approach lacks a comprehensive learning environment for the user. Other simulators offer a comprehensive learning environment but are too expensive for the classroom. The present design provides the benefits of a comprehensive learning environment through multiple forms of stimuli while maintaining a price level that makes the unit readily available for the classroom setting.

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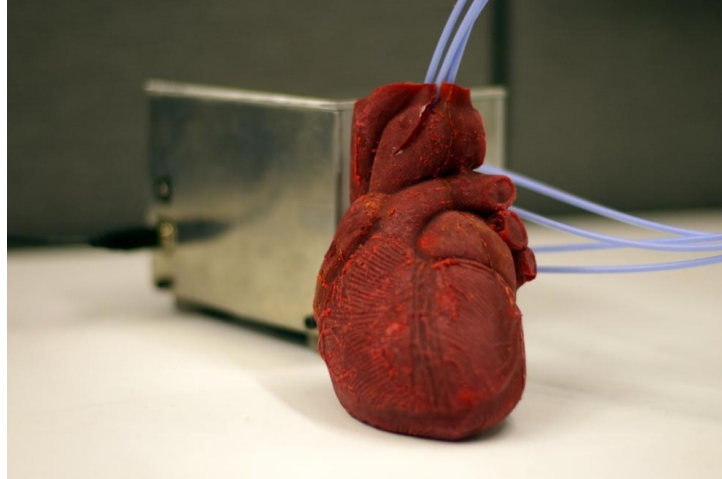
Figure 1. USB connected, beating heart simulator.

1. Methods

In pursuit of designing a suitable heart arrhythmia simulator, several possible configurations were conceptualized and prototyped. Initial prototyping included investigating the use of servo motors as a drive mechanism and writing rudimentary control code for use on a microprocessor. Ultimately, the use of servo motors was abandoned in favor of solenoid actuators to manipulate the simulator due to high noise levels and low power capacity. Additionally, a control algorithm and coupled graphical user interface (GUI) was developed to both control the solenoid actuation and provide the user with enhanced feedback and control. After cycling through several design iterations, a final design was reached that satisfied the design requirements and the budget constraints.

2. Results

The beating heart simulator prototype was designed to provide the user with an immersive environment for learning the variations between several heart arrhythmias. The device incorporates computer software to provide the visual and auditory feedback to the user while simultaneous tactile information is fed to the user through a USB connected heart model (Figure 1).

The tactile portion of the device uses pull-style linear solenoid actuators to provide conversion between input electrical signal from the printed circuit board (PCB) and output translational motion at the heart model. The prototype uses four solenoid actuators, one for each chamber of the heart model. When the solenoid actuator is activated by an electrical signal from the PCB, the solenoid core retracts into the stationary coil thus applying tension to the rigidly connected wire. The wire applies a force to the heart model, through an anchor, which produces a displacement in the model wall.
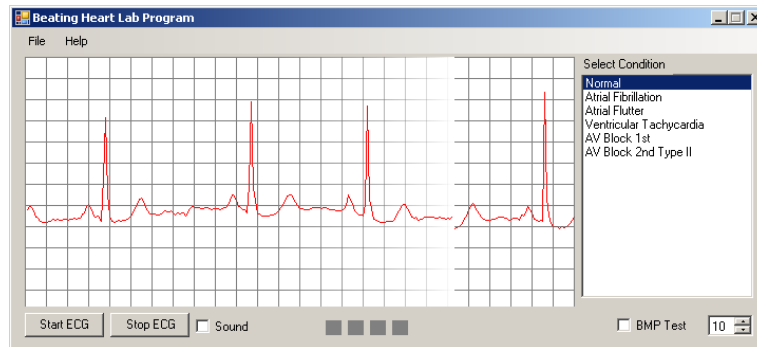
Figure 2. Main program screen.

The computer software, written in Visual C#, presents the user with a welcome screen when first opened to make sure the USB kit is connected and communicating properly. Once the program has started, the main user interface is shown (Figure 2). From here the user can select from a variety of heart conditions which will automatically start the EKG script that reads a pre-recorded data file approximately 30 seconds in length [6]. The script will continue to play on loop until the user selects a new option or quits the program.

3. Conclusions

Further development is needed in several areas. Continued enhancement of the GUI to include additional information about each heart condition could be incorporated to enhance the user experience. Additionally, a more sophisticated EKG analysis algorithm could provide more complete data to the end user. Beyond this, the simulator should undergo comprehensive validation studies to ensure that it meets the intended design goal of being a useful educational tool for health-care students.

In the long-term outlook, the simulator could potentially be marketed as a learning tool for K-12 schools as well as hospitals or clinics as a means of enhancing patient comprehension.

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