Medical Virtual Integrated Training Environment (VITE)

Faisal Ashour, Matthew Conley, Michael Lewis, Jason Mellott, Karina Rusnak
Department of Modeling, Simulation and Visualization Engineering, Old Dominion University
Norfolk, Virginia
fasho001@odu.edu, mconl013@odu.edu, mlewi049@odu.edu, jmell008@odu.edu, krusn002@odu.edu

ABSTRACT

The purpose of this paper is to present a virtual integrated training environment (VITE) under development by ODU and EVMS for use with manikin-based medical training, in manner that exploits computer communication to the manikin. Current medical training uses a self-contained commercial manikin in an ordinary classroom lacking other medical equipment. This system includes tablet-based simulators that represent real medical equipment that is able to directly interact with the manikin. A previous capstone design class also developed a virtual environment with manikin-based training [2]. That group was able to develop virtual devices but was not able to get the devices to communicate with the manikin and vice versa. VITE will establish a communication network that integrates the functionality of the manikin with its surrounding environment. The manikin will function with devices that are able to send and receive information. The paper begins with a physical description of the overall system. Then, the system architecture and system components are detailed. The paper concludes with a functionality description of the prototype devices. A prototype system is currently being developed for Eastern Virginia Medical School as part of a M&SE Capstone Design Course at Old Dominion University.

ABOUT THE AUTHORS

Faisal Ashour is currently a senior student pursuing a Bachelor’s Degree in Modeling and Simulation Engineering at Old Dominion University with a minor in Engineering Management. Mr. Ashour has an interest in medical simulation specifically in the medical simulation-training field.

Matthew Conley is currently a senior student pursuing a Bachelor’s Degree in Modeling and Simulation Engineering at Old Dominion University with a minor Computer Science.

Michael Lewis is a student at Old Dominion University, studying in the accelerated program for Modeling and Simulation with a minor in Computer Science. He currently works alongside school, and has an interest in video game design, military technology, and audiovisual arts.

Jason Mellott is currently a senior student pursuing a Bachelor’s Degree in Modeling and Simulation Engineering at Old Dominion University. Mr. Mellott is currently unsure as to where he intends to take his degree after graduating but does intend to pursue further studies at a later time.

Karina Rusnak is currently a senior pursuing a Bachelor of Science at Old Dominion University in Modeling and Simulation Engineering with a minor in film and video studies. Ms. Rusnak has interest in the entertainment industry including amusement park attractions, feature films, and television.

Medical Virtual Integrated Training Environment (VITE)

Faisal Ashour, Matthew Conley, Michael Lewis, Jason Mellott, Karina Rusnak
Department of Modeling, Simulation and Visualization Engineering, Old Dominion University
Norfolk, Virginia
fasho001@odu.edu, mconl013@odu.edu, mlewi049@odu.edu, jmell008@odu.edu, krusn002@odu.edu

INTRODUCTION

The Modeling, Simulation, and Visualization Engineering (MSVE) Capstone design team (MCDT) realizes the opportunity to enhance virtual medical manikin-based training. MCDT is creating a prototype system for Eastern Virginia Medical School (EVMS) that improves their current manikin-based training environment. Currently, when a training simulation is conducted using the manikin, a technician is required to implement changes to the manikin's physiology. MCDT's new system, Virtual Integrated Training Environment (VITE), introduces virtual devices that are able to communicate with the manikin and update it's physiology without prompt from the technician. To achieve this, MCDT will develop a communication network that administers all system communication. The purpose of this system is to enhance the effectiveness of medical manikin training by creating a more realistic training environment that allows learners to use virtual medical equipment that reflects its real life counterparts. The system will also reduce the cost associated with supplying real medical equipment.

This paper is divided into six sections. The first section is the introduction. The second section provides background literature on current medical virtual training that supports the need for VITE. The third section details the current physical training environment at EVMS, introduces the physical system of VITE, and lists the design objectives of the system. Section four discusses the system architecture and the software components of the system. Section five details the functionality of the devices that will be used in the prototype, and section six concludes the paper.

BACKGROUND

Manikin based training is used throughout the medical community to train people in a controlled environment. Difficulties exist in incorporating manikin-based simulations into nurse training, causing extra time to be spent learning how to use and set-up the system (Jansen, Johnson, Larson, Berry, & Brenner, 2009). VITE will address both of these issues. The setup is an automated process that is conducted by a technician. The user will be able to get familiar with new virtual devices outside of the training environment on mobile devices to be more prepared for the simulation.

A previous capstone class developed a similar project with manikin based training that utilized the SimMom manikin (Gardner et al. 2013). This system highlighted the importance of incorporating external devices into the simulation. The drawback was that this system did not connect the devices to the manikin. This lack of communication required a technician to physically enter changes to the manikin's software.

Virtual representations of real medical devices are currently being used in the medical community. Simulators of medical devices that utilized touchscreen inputs were developed to interact with manikins (Samosky, Thornburg, Karkhanis, Petraglia, Strickler, Nelson, & Robinson, 2012). A virtual defibrillator was created that replicated the functionally of the real defibrillator. The defibrillator program resided on a tablet that was connected to fabricated paddles. The paddles were sensor enhanced physical analogs. When pressed to the manikin's chest a simulated waveform would display on the tablet's interface. This demonstrated that real medical devices can be replaced with virtual versions of those same devices and achieve the same results in a training environment.

Virtual simulations for training purposes can be executed on tablets (Cenydd, John, Phillips, & Gray, 2012). A Ventricular Catheterization Simulation (VCath) was developed as a tool used to train neurosurgeons to perform catheterization of the lateral ventricle. This demonstrates that virtual simulation can be used for training medical students to perform specific operations. VCath operated in two different modes; procedure mode and practice mode.

Procedure mode would conduct the actual simulation and practice mode would allow the user to practice and get familiar with the app. VITE will utilize both of these modes

PHYSICAL SYSTEM

The physical system represents the entire training environment. This section first describes the current training environment at EVMS. Then, the new system created by MCDT is described.

Current System

Figure 1 represents the current training environment at EVMS. The student, instructor, and the manikin system, SimMan, are located inside the environment during the training scenario. The technician is located outside of the environment and controls the SimMan program. The student interacts with the manikin while the instructor and the technician observe the student's actions. The instructor records the action for their review. The technician physically implements the student's actions in to the manikin software.

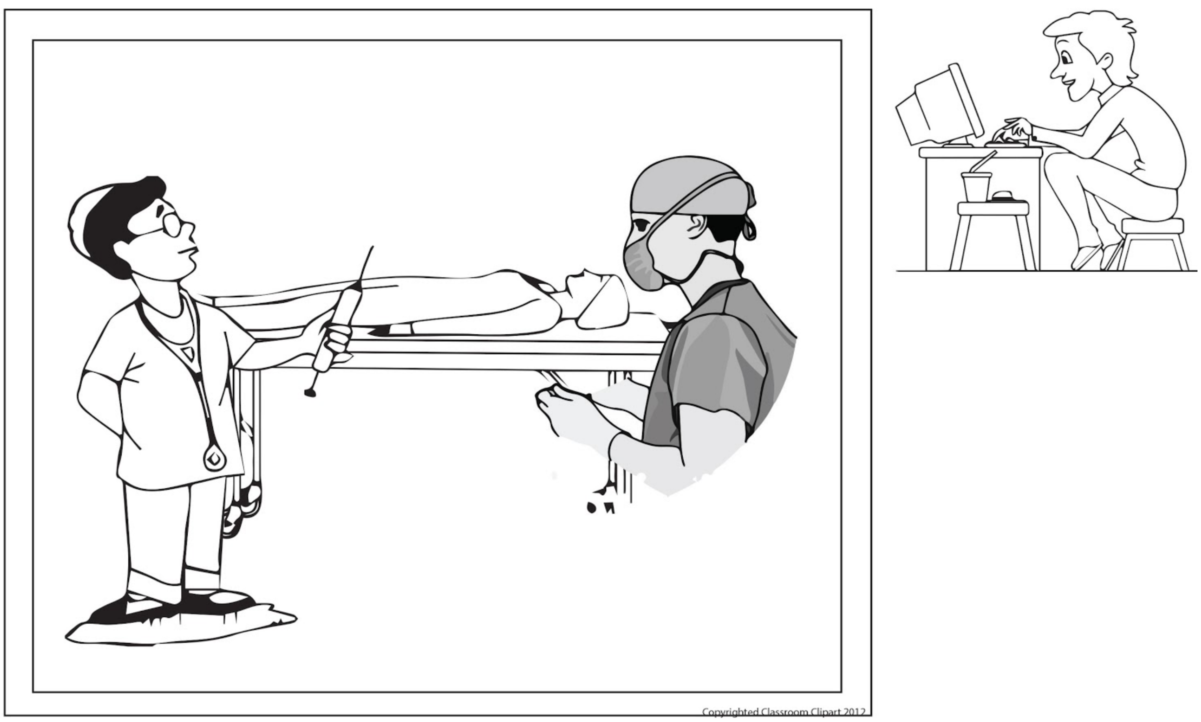

Figure 1. Current System

New System

Additions to the current system will create the new system, VITE. The new system features a communication network that enables the manikin to connect to other devices in the system. The new system adds a new component to the SimMan computer. Previously, only the SimMan program resided on the SimMan computer. The manikin is directly connected to the SimMan program that controls its physiology (Swamy, Bloomfield, Thomas, Singh, & Searle, 2013). Now, a management program will also reside on the computer and be operated by the technician. This management program centralizes all communication in the system. All messages must pass through the management program. SimMan will send and receive information from other system devices through the management program.

Another addition to the system is virtual devices. Virtual devices are representations of real medical equipment that can function within the simulation to enhance the training environment at minimal cost. These virtual devices will communicate with the manikin by sending inputs, receiving outputs, and observing the manikin's behavior.

Examples of real medical equipment that virtual devices can represent are an IV pump and a patient monitor. The student will directly interact with the IV pump. The IV pump will send drug information to SimMan that will automatically adjust the manikin's physiology. The patient monitor is able to receive medical parameters from SimMan that represent its current physiology, and display the parameter corresponding numerical values and waveforms. A physical representation of VITE is shown in Figure 2.

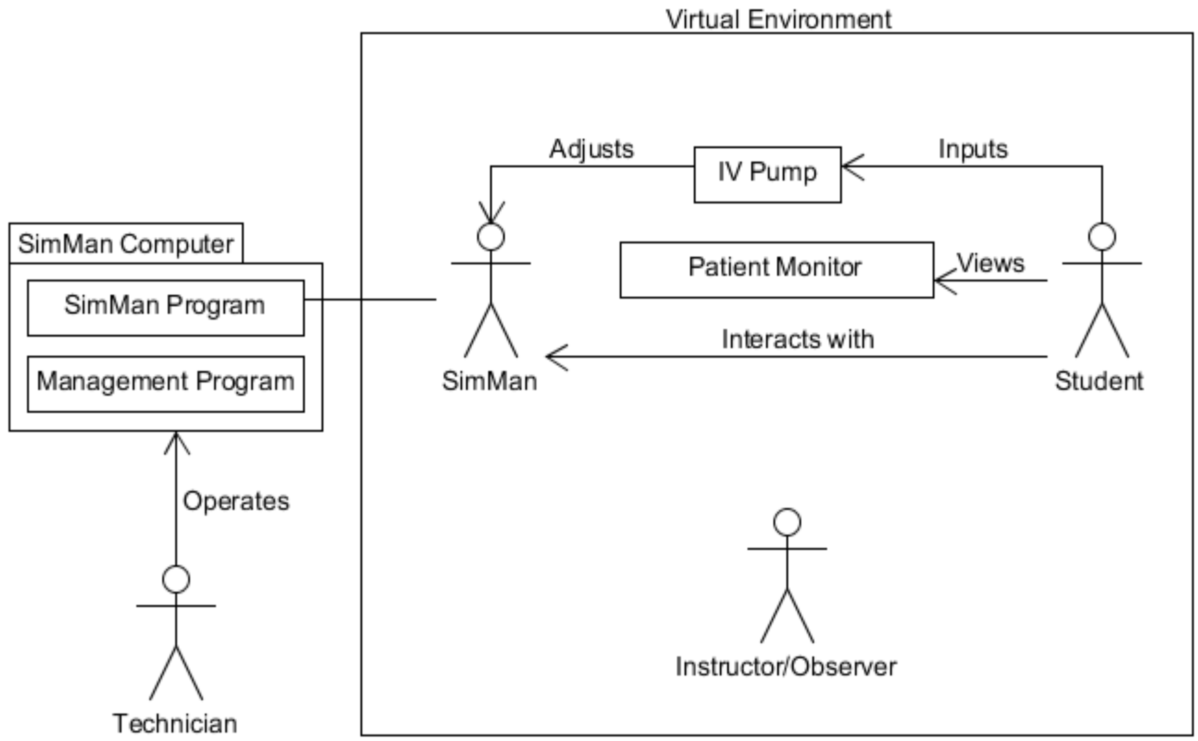

Figure 2. New System

Design Objectives

The design objectives for this system are as follows:

- System Communication Network - All virtual devices will be able to communicate directly with the manikin and automatically update the manikin's physiology. The manikin will be able to send information to other virtual devices in the system. Multiple virtual devices can communicate will each other.
- User-friendliness - The system will be efficient without being difficult to learn. This helps ensure the short and long term use of the system. The system will also have an automated and fast setup process.
- Expandability - The design of the system makes it easy for additional virtual medical devices to be developed and added to the system at a later date. The system will recognize the devices without having to be reworked. Virtual devices can be added and removed without affecting the rest of the system. In addition, the system supports a variety of medical manikin systems.

SOFTWARE ARCHITECTURE

The software architecture describes how the system's software is combined to represent the physical system. The system is organized as a star topology as illustrated in figure 3. A management program is the central point of all communications between the system components. This structure enables the user to add and/or remove virtual devices without disturbing other system software. With the star topology in place, a message must go from one device, to the management program, and then go from the management program to other device. This will require many separate components to be developed in order to support this infrastructure.

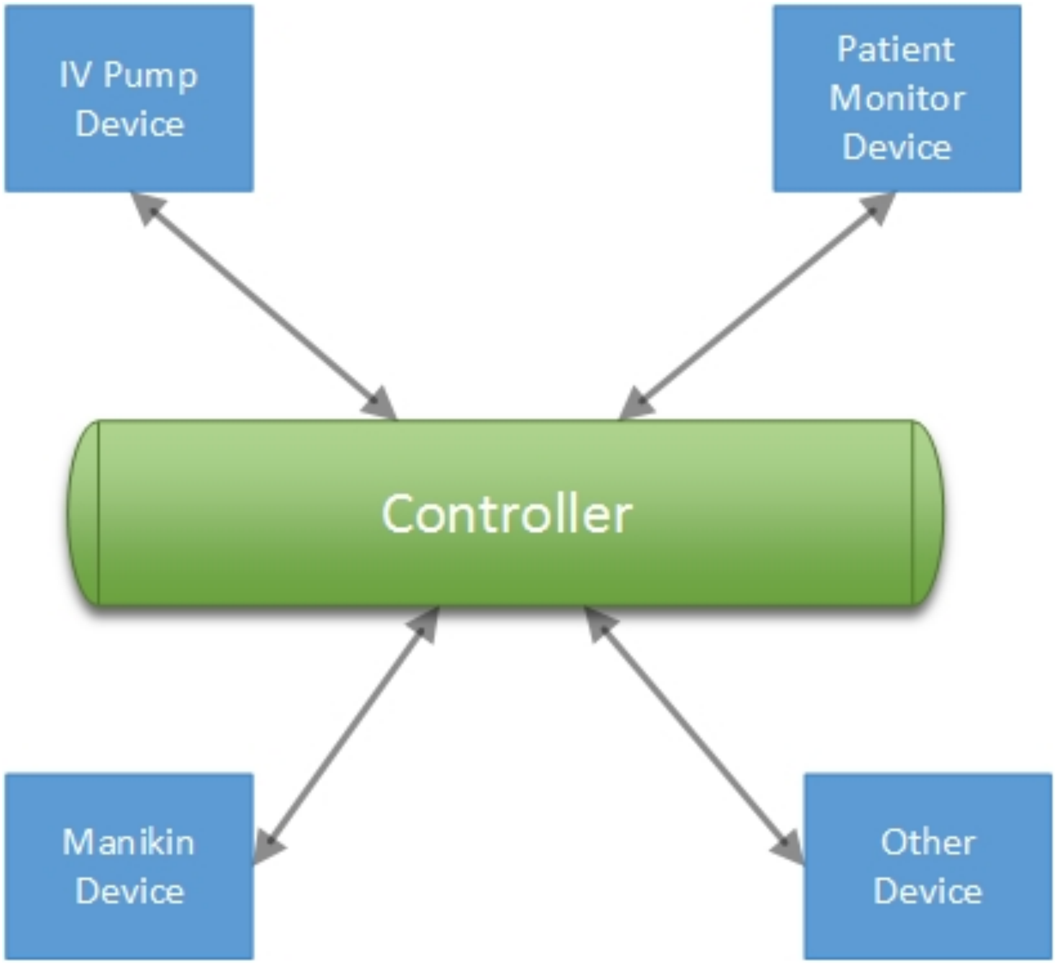

Figure 3. Communication Network

Software Components

The software components are the parts of the system architecture. Each component connects with other components to form the program. These programs connect with other programs to form a system. The programs are separated from each other and do not require each other to function properly. The central program of this system is the management program, forming the center of the star topology the system uses. The management program connects to the other device programs within the system. The management program acts as the communication hub for the system. The devices are unable to communicate directly with each other, and only can communicate through the management program. The management program's main purposes are to start the system and store scenario related information, decide which devices require a message, and send messages to devices.

Figure 4 represents the architecture of the system and draws the connections between the software components. The architecture contains six components: the Communication Network, Software Controller, SimMan Computer, Patient Monitor, IV Pump, and Other Devices. Each component contains at least three individual components that represent the communication program, the interpreter, and the device program.

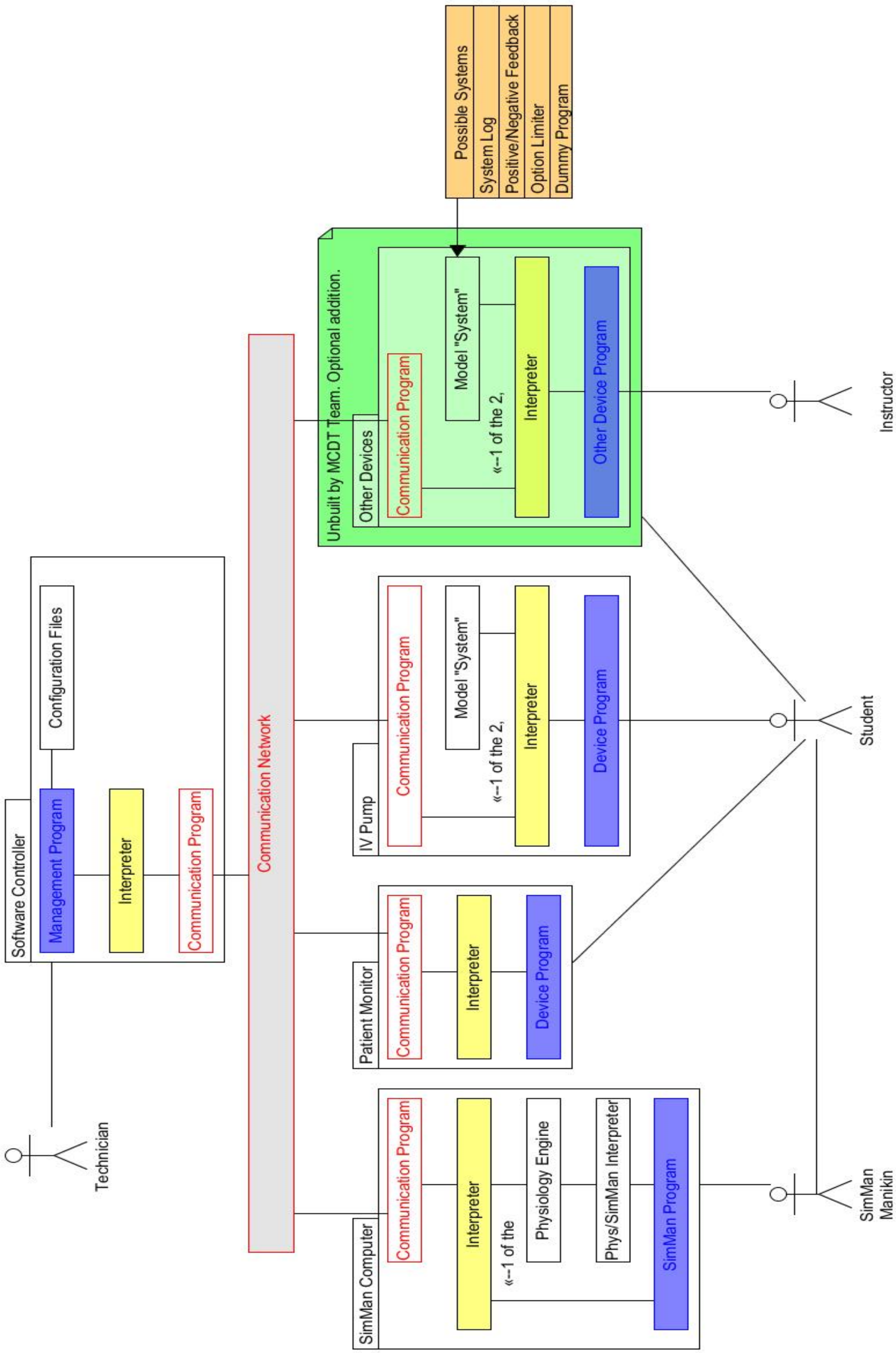

Figure 4. System Architecture

The system components are as follows:

- The communication network represents the network that messages will pass through to reach the various parts of the system. All components of the system are connected to this network. Messages moving throughout the network will be written in a universal format that all parts of the system can understand.
- The communication programs send and receive messages in a universal format. The communication programs are connected to communication network and it's relative interpreter.
- The interpreter changes device messages into a universal message format. An interpreter is connected to its relative device program and communication program. Each interpreter will function differently in response to the attached programs.
- The software controller contains the management program. The management program acts as the center of communication. It receives messages and determines what location the messages are sent to. The starting point of the system setup is located here. The management program is connected to the configuration files and an interpreter. The configuration files are what the management program will use to obtain scenario information to set up the system. The configuration file contains a list of needed devices and relative information being sent through the system.
- The device programs are unique to each device and send and receive messages to and from its relative interpreter in its own unique format. This program accepts user input and interpreted messages that can change the state of the system and the physiology of the manikin. Two devices being developed are an IV pump and a patient monitor. The SimMan program is a device program that has already been developed.
- The Patient Monitor and IV Pump represent the two virtual devices that will be built for the prototype. The IV Pump has a Model System component. This Model System replaces the entire system from the IV Pump's communication program to all other components in the architecture in a simplified form. This Model System is what the IV Pump connects to when the device is in independent mode. Enabling the user to practice with the device outside the virtual environment. The communication program is what the device uses when in integrated mode and interacts with the rest of the system.
- The Other Devices component determines the components that an extra device needs before it can be integrated into the system. It will have the same communication pathway of the current devices as well as an alternative path to a model system that can have the capability to provide the system with an activity log, physiology engine, dummy program, or feedback display.
- The SimMan Computer represents the manikin the prototype will use. Unique to this component is the physiology engine and Phys/SimMan Interpreter components. SimMan can be modified to send messages from its program to the communication network through two paths. On the first path, the SimMan program sends a message directly to its interpreter, which sends the message to the communication program and out into the network. On the second path, the SimMan program sends information to a physiology engine that would need to be built, which would send the message to the interpreter, then to the communication program and out into the network.

FUNCTIONALITY

This section describes the functionality of the each device in the system. There are three devices in this system; the manikin, patient monitor, and IV pump.

- Manikin - The manikin that will be used in this system is Laerdal's SimMan. However, the system will be able to work with any manikin and is not exclusive to SimMan. The goal of the system being built is to minimize the technician's role in the simulation. For example, when a drug is injected into manikin through the IV pump, the manikin program will automatically realize that it has been injected with a drug and adjust its physiology parameters accordingly. SimMan will send it's vitals to the patient monitor at initialization and whenever there is a change in vitals, SimMan will resend that corresponding vital.
- Patient Monitor - The patient monitor device in this system replicates the functionality of a standard patient monitor and is designed from the Dash 4000 Patient Monitor (GE Medical Systems, 2005). The device will be an app on a tablet and will display relative parameters and waveforms that represent the manikin's

physiology. The monitor has preprogrammed layouts. Figure 5 displays an example layout with four waveforms and three parameters. The user will identify the monitor layout and the parameter content in the configuration file prior to starting the simulation. An example of a waveform is electrocardiogram (ECG) that represents the heart's activity. An example of a parameter is respiratory rate (RR). The patient monitor will receive vitals from SimMan and will repeat the same wavelength and vital amount until the monitor receives a parameter update message from SimMan.

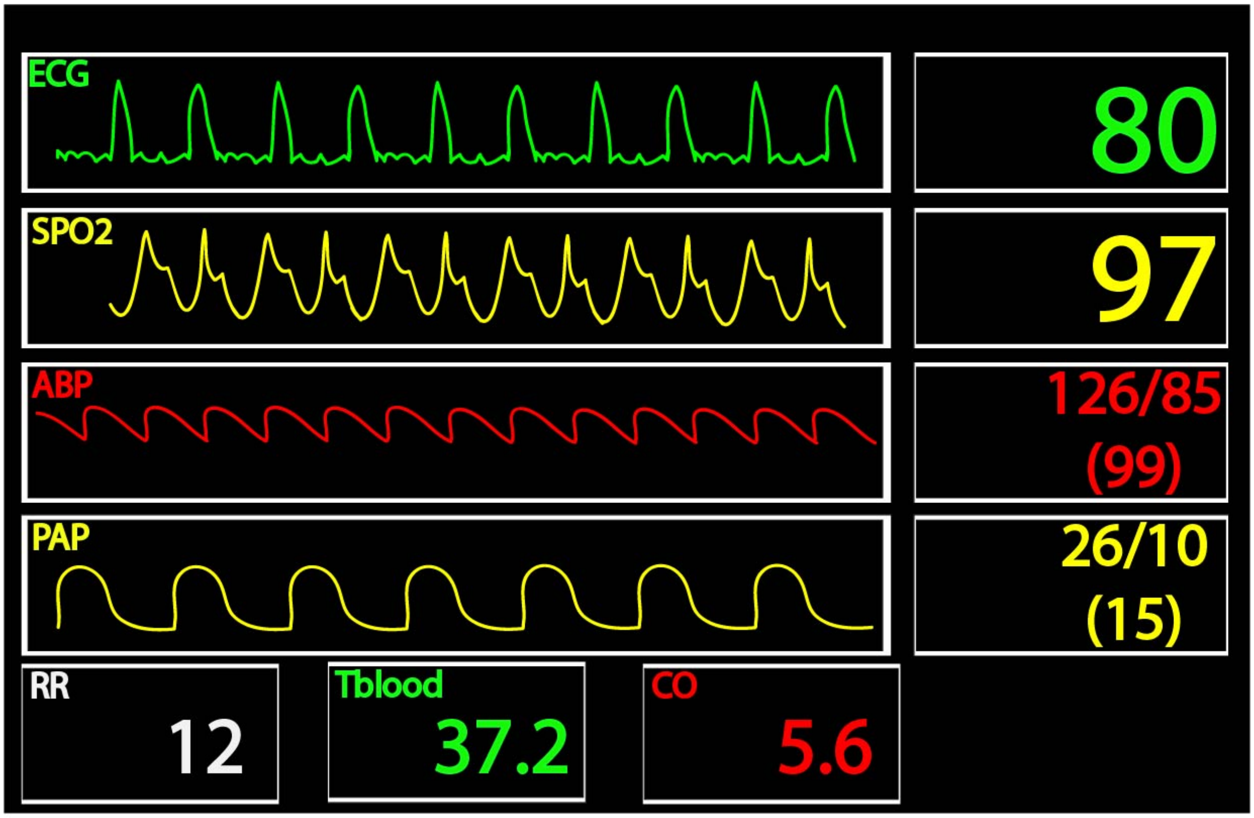

Figure 5. Example of Patient Monitor Display

- IV Pump - The IV pump device represents a real medical IV pump. The IV pump program is designed from the Plum A+ Infusion Pump (Hospira Inc., 2005). The device will be an app on a tablet with the user interface and functionality that mimics an IV pump. Figure 6 represents the user interface of the IV pump program. Users will directly interact with the IV pump. The user will command the IV pump to send an infusion message to SimMan. The message contains the type of drug being infused and the infusion rate.

  The IV pump has two modes of operation integrated and independent. Integrated mode is used with the virtual environment and will send messages to the manikin. Integration mode enables the IV pump to receive and send messages throughout the system. Instructional mode enables the IV pump to be used outside of the training environment. The purpose of this mode is to allow users to interact with the program and learn how the program works prior to the training session.

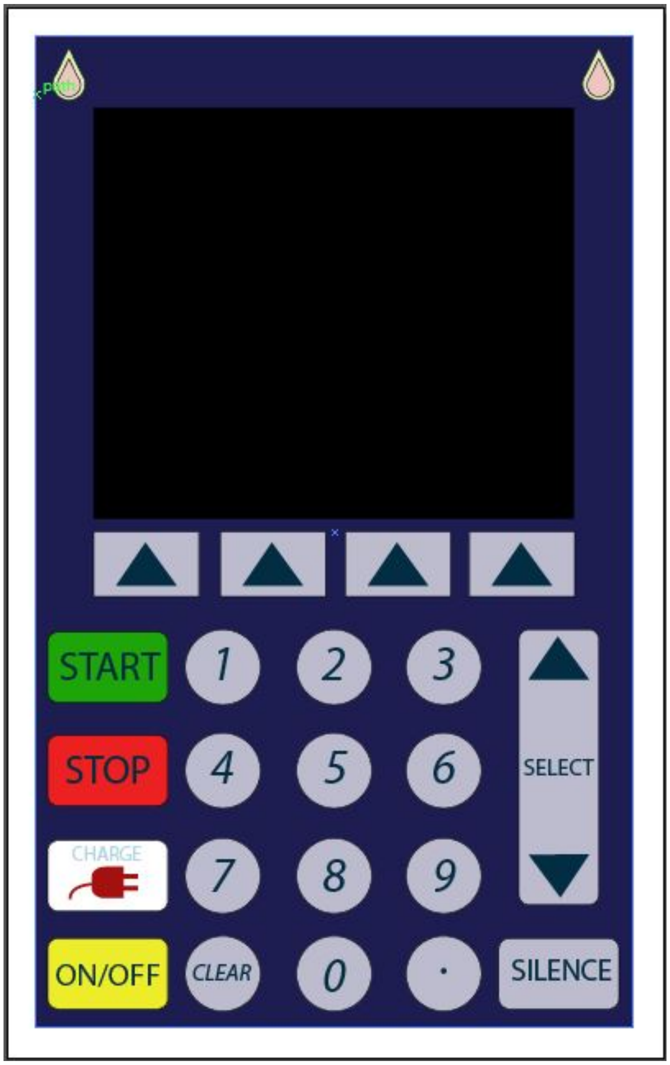

Figure 6. IV Pump Interface

CONCLUSION

VITE will enhance the current manikin-based medical training by increasing the realism of the simulation. The addition of a communication network will allow the SimMan system to communicate with virtual medical devices, decreasing costs of using real medical equipment in simulations, and creating a system that will be easier to use than the original system. This system allows the users to interact with devices other than the patient, as it would be in the real world. VITE is also customizable due to the ability to easily develop additional software and add new devices. Emerging medical manikin-based training with MSVE will allow a seamless training experience for the user.

ACKNOWLEDGEMENTS

We would like to thank our instructors at Old Dominion University, Dr. Roland Mielke and Dr. James Leathrum, for mentoring us in this project. We would also like to thank the following people at EVMS for serving as our clients: Bob Armstrong from the National Center for Collaboration in Medical Modeling & Simulation, and Geoffrey Miller and Andrew Cross from the Sentara Center for Simulation and Immersive Learning.

REFERENCES

Cenydd, L. A., John, N. W., Phillips, N. I., & Gray, W. P. (2012). VCath: a tablet-based neurosurgery training tool. *Studies in health technology and informatics*, *184*, 20-23.

Gardner, T., Lane, S., Lezzi, L., & Nhan, T. (2013). Virtual Labor Delivery (VLAD): A Simulated Environment for Obstetrics Training.

GE Medical Systems (2005). *Dash 3000/4000/5000 Patient Monitor Operator's Manual*. General Electric Company. Retrieved from http://www.frankshospitalworkshop.com/equipment/documents/ecg/user_manuals/GE Dash 3000,4000,5000 - User manual.pdf

Hospira Inc. (2005, October). *System Operating Manual Plum A+*. Retrieved from http://www.meql.com/Manuals/Abbott-Hospira-Plum-A-116-Manual.pdf

Jansen, D. A., Johnson, N., Larson, G., Berry, C., & Brenner, G. H. (2009). Nursing faculty perceptions of obstacles to utilizing manikin-based simulations and proposed solutions. *Clinical Simulation in Nursing*, *5*(1), e9-e16.

Murphy, J. G., Cremonini, F., Kane, G. C., & Dunn, W. (2007). Is simulation based medicine training the future of clinical medicine?. *European review for medical and pharmacological sciences*, *11*(1), 1.

Samosky, J. T., Thornburg, A., Karkhanis, T., Petraglia, F., Strickler, E., Nelson, D. A., ... & Robinson, E. (2012). Enhancing medical device training with hybrid physical-virtual simulators: smart peripherals for virtual devices. *Studies in health technology and informatics*, *184*, 377-379.

Swamy, M., Bloomfield, T. C., Thomas, R. H., Singh, H., & Searle, R. F. (2013). Role of SimMan in teaching clinical skills to preclinical medical students. *BMC Medical Education*, *13*, 20. doi:10.1186/1472-6920-13-20