ITEC 2019 – The Art of Designing and Rapidly Prototyping Medical Training Technologies

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Abstract — While many injuries are common, and diagnosis is simple, hands-on training of clinicians in treatment is neither common nor practical given current physical training models. The injuries sustained can be complicated and the prescribed interventions require an anatomically accurate training model but in many cases physiological feedback can be minimized in training the immediate response for battlefield injuries. Durability and low lifecycle cost become key drivers for training common battlefield injuries so that repetitive training cycles can be performed. a collaborative partnership with stakeholders, users, and sponsors contribute to the success of the technology development. This presentation will discuss the processes and tools used to rapidly develop medical training technologies that meet the needs of the Warfighter today as well as the methods to acquire and incorporate expert feedback, the lessons learned, and recommendations for future work.

1 Introduction

With the introduction of 3D printing technologies, evolving additive manufacturing capabilities, and commercial packaging of miniature processing and sensor technology, moving rapidly from a concept to implementation is becoming prevalent in today's medical training development environment. While many injuries are common, and diagnosis is simple, hands-on training of clinicians in treatment is neither common nor practical given current physical training models. The advanced manufacturing capabilities can benefit medical training by accelerating the iterative design and manufacturing process.

2 Objectives

This paper will share how collaboration and iterative development can result in medical training technologies that can address emerging training gaps. The objective of this paper is to share the approach and lessons learned as well as areas of focus for future work.

3 Approach

Current training curricula primarily consist of lectures and watching an experienced clinician perform the technique on a live patient. Despite numerous advances in medical simulation, the market currently lacks high-fidelity Part Task Trainers (PTTs) that enable learners to have multiple opportunities for skill practice and feedback using a repeatable and inexpensive training platform. In the U.S. military, medical training gaps are often encountered due to the nature of the injuries found on the battlefield and during training compared to the capabilities of current high-fidelity human patient simulators (HPSs). Although current HPS capabilities can run very sophisticated and accurate physiological models mimicking a broad array of medical conditions, they often lack specific detailed anatomy required to properly diagnose and treat common battlefield injuries. Additionally, many of the injuries and required treatments require destructive procedures such as cutting, drilling, or puncturing the skin and underlying tissues, to be performed on the specific anatomy. Training the large number of Soldiers required or desired to have these skills quickly becomes cost prohibitive when applied to current HPSs. The injuries sustained can be complicated and the prescribed interventions require an anatomically accurate training model but in many cases physiological feedback can be minimized in training the immediate response for battlefield injuries.

Durability and low lifecycle cost become key drivers for training common battlefield injuries so that repetitive training cycles can be performed. A disciplined engineering process coupled with initial investment in critical needs analysis can result in refined requirements that facilitate rapid and iterative prototyping of PTTs that can address medical training gaps. Preliminary prototypes are used to define derived requirements and fine tune designs with Subject Matter Expert (SME) inputs. These prototypes are digitally designed and developed using 3D printing and other additive manufacturing techniques fostering rapid and iterative collaboration between the engineering team and SMEs. Prototypes are augmented with embedded sensors and processing to facilitate realism and trainee feedback. Finally, a collaborative partnership with stakeholders, users, and sponsors contribute to the success of the technology development. This presentation will discuss the processes and tools used to rapidly develop medical training technologies that meet the needs of the Warfighter today as well as the methods to acquire and incorporate expert feedback, lessons learned, and recommendations for future work.

3.1 Requirements and Critical Task Analysis

Requirements often include developing a low-cost, high-fidelity simulator that can be easily reused, maintained and stored. Requirements begin with a literature review to discern all aspects of the medical procedure and to identify training gaps with existing simulators in the market. A Critical Task Analysis is conducted with Subject Matter Experts (SMEs) to better understand the details of the procedure and necessities of a simulator. The team gathers more accurate information regarding these aspects of the provider's interaction with a patient to further refine the simulator requirements:

- ***Relevant signs and symptoms***: including pain, numbness, tingling, swelling etc.
- ***Key desired components***: anatomical landmarks, anatomical and physiological functionality, appearance, differences in different patients, etc**.**
- ***How is the patient history collected and diagnosis determined***: including mechanism of injury, physical examination, testing procedures, and visual comparison?

Technical requirements and constraints are then developed in concert with the elicited data from the users to form a complete set of requirements for the development of the systems.

3.2 Spiral Development

A system engineering process is utilized to guide the design of the end training products. Requirements are mapped to subsystems as well as integration and test procedures to ensure that the system is complete and testable. Integration of artistic components is prioritized to ensure the end product will benefit from multiple iterations of the design. Artistic or "soft" components often provide design and integration issues especially when movement is involved. By prioritizing the artistic components, design issues can be identified and resolved earlier in the development cycle allowing for a more complete and accurate design. Design updates are implemented throughout the development lifecycle to address critical issues as early as possible.

Rapid prototyping and manufacturing processes are employed to facilitate multiple prototyping iterations allowing both technical and user evaluations to influence requirement and design updates for successive iterations. This iterative process coupled with rapid prototyping capabilities shortens the total design phase of the system by allowing artistic aspects to be coupled with underlying and supporting electromechanical systems. 3D printing and other manufacturing techniques are utilized in each iteration allowing quick turn and testing of new design concepts based on incremental integration and testing at subsystem and system levels. Major design changes can be produced in a day or less in some cases. Additional targeted integration and test can be defined to address identified issues as they arise in the development cycle. Issues related to the integration of artistic aspects of the system are discovered earlier in this approach. Small changes to a mold can be rapidly printed and testing of a modified soft tissue component employed within hours of a design change. By utilizing rapid prototyping and manufacturing throughout the design phase both major and minor issues are identified and worked in the successive iterations.

3.4 Testing

Usability studies are conducted at various training centers using the prototypes at different phases of development. The various locations provide access to skilled and unskilled participants with similar backgrounds. The purpose of these studies is to compare the fidelity and functionality of the prototype simulator to the clinicians experience with a live patient. Participants complete a demographic questionnaire, articulate their decision making processes while performing the procedure, and answer a series of questionnaires about their experiences and opinions. The studies help to focus the development moving forward.

4 Lessons Learned

The art of designing and rapidly prototyping medical training simulators relies on an iterative methodology that incorporates user feedback and usability data throughout the design and development process. By allowing users to provide input and feedback early and often, the simulator will better address their training gaps. The goal is to develop training technologies that are relevant, affordable, and maintainable.

Author/Speaker Biographies

Ms. Angela M. Alban is President and CEO of SIMETRI, Inc., based in Winter Park, Florida. Ms. Alban has a degree in Mathematics and Computer Science from Emory University and a Master of Science in Computer Engineering from the University of Central Florida. She completed the Defense Systems Management College Advanced Program Manager's Course to parallel 23 years of experience in the Simulation and Training Industry.

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