A Virtual Surgical Environment for Orthopaedic Surgical Training

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INTRODUCTION

• The traditional way of surgical teaching involves
  • Residents first merely observing a ‘live’ surgery
  • Practicing on cadavers
  • Practicing on animals
• These methods have their own demerits
• Virtual environments will
  • accelerate and supplement existing training approaches
  • provide more surgical training opportunities
  • facilitate a larger pool of better trained medical doctors
INTRODUCTION

• Current trends
  • For medical surgical training
  • heart surgery, laparoscopic surgery, etc

• Simulator called VSE (Virtual Surgical Environment)

• Scope: LISS plating surgery (orthopaedic)

• LISS - Less Invasive Stabilization System

• For dealing with fractures of the femur
BACKGROUND

• Lesser availability of simulators in orthopaedic surgery
• Developed simulators have not emphasized or adopted Sys Eng (SE) approaches
• Expert surgeons not played an important role in past efforts
• Need for a Systems engineering based approach
• Importance of Information Models as a foundation to design/build surgical simulators
• Use of Next Generation Internet technologies
• Creation of IoT based Cyber Training framework
ICSE and IoT based APPROACH

• Information Centric Systems Engineering (ICSE) approach

ICSE = SYSTEM ENGINEERING APPROACH + INFORMATION MODELING

• IoT Framework: support Cyber Training activities using Next Generation Networking Principles

• Info Models: A structured foundation to help understand core phases and their relationships
  • engineering Enterprise Modeling Language (eEML)
Develop a simulator for LISS plating surgery

Provided a structured foundation to design and build simulator (VSE)
Facilitated adoption of SE approach
Designing the IoT based simulator framework

eEML model used for the design of the VSE
Info Model of Surgical Steps (Eg: Fracture Reduction)
LISS PLATING STEPS

Steps Involved in LISS surgery

- Pre-operative planning
- Implant choice
- Fracture reduction
- LISS assembly
- LISS insertion
- Screw insertion
- Insertion guide detachment
- Closing the wound

LISS components (from Synthes Manual)
VSE ARCHITECTURE

- Cyber Resources
  - LISS Assembly
  - LISS Insertion
  - Position Training
  - VSE Manager
  - Haptic Manager
  - Screw Insertion
  - Guide Removal
  - Fracture Reduction

- Expert Surgeon
- Resident
LISS ASSEMBLY TRAINING MODULE

- User practices assembling the LISS plate with help of avatar

Steps Involved in LISS Assembly Training Module
LISS INSERTION TRAINING MODULE

- Users practise process of insertion of LISS plate inside the human leg

Avatar interacting with user
Positioning of the plate in between the distal and proximal is important.

- Achieved by using a red yellow and green light color indication scheme.
  - Green: desired position/orientation
  - Yellow: close but not desired
  - Red: wrong position/orientation
HAPTIC INTERFACES

User interacting with VSE using a Phantom haptic interface
NETWORK BASED SIMULATION ENVIRONMENT

- The VSE can be accessible from remote locations using GENI
- GENI = Global Environment for Network Innovations (GENI)
- An initiative led by the National Science Foundation
- Design of the Next Generation Internet based on advanced networking characteristics
  - multi-gigabit bandwidth
  - low latency
  - software-defined networking and/or control over geographic location of resources.
Architecture for the telemedicine surgical application
• The surgeon and students do not have to be at the same physical location during the training.
• Each participant (surgeon or student) is presented with his or her own instance of VSE.
• Collaborative learning facilitated
ROLE OF EXPERT SURGEON

• Dr. Cruz has been involved since 2012
• Dr. Cruz is an orthopedic surgeon, professor and former head of the orthopedic department at TTUHSC
• Multiple visits by OSU team, other interactions by skype, phone calls
• Knowledge expert in this project

Dr. Cruz testing the VSE pilot module
ASSESSMENT OF LEARNING ACTIVITIES

- Validated through at the department of orthopaedic surgery at the Texas Tech University Health Sciences Center, El Paso
- Spread over 3 years
VALIDATION

Medical students and residents using the VSE for Validation
Majority of residents demonstrated improvements in understanding of LISS surgical processes
CONCLUSION

- System of Systems (SoS) engineering approach played an important role
- Role of expert surgeon
- Creation of information centric process model of LISS plating process
- Network based capability of simulator
- Validation studies conducted demonstrated effectiveness of IoT based surgical simulator created
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Thank You.

Questions?
Info Model of Surgical Steps (Eg: Fracture Reduction)
BENEFITS OF SE APPROACH

- Two modules were created with and without adoption of systems engineering principles
- Modules created with SE approach showed these benefits
- Reduced lead time to design and build the simulator modules (30% reduction)
- Reduction in number of changes suggested by surgical experts after initial implementation (30% reduction);
Other benefits

- better traceability of decision making in the overall process while developing various modules of the simulator.
- Involving the expert surgeons in the design process enabled the programmers and designers to have a better understanding of the intricacies in the surgical training objectives
- while reducing the number of changes in the simulation content and user interactions after each of the modules were completed.
Other Benefits

• Other feedback obtained from the project teams indicated that when systems engineering approaches were adopted, they were able to understand the complexities of the simulation better.

• Creating the information model of the surgery process details played a key role in the simulator building team being able to better understand what training elements had to be emphasized along with the pre-conditions associated with many of the surgical training steps.