Simulation and Game Technology in Medical Education

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Approved for Public Release.
The Surgical Pilot – a common analogy
Creating Experts & Eliminating Errors

10,000 hours to become an expert - Gladwell
“There is no excuse for the surgeon to learn on the patient.” – William Mayo, 1927
Pilots do not learn on passengers.
Classical Elements (Empedocles, 450BC)
Classic Military Simulation Elements

Live

Virtual

Constructive

Games
Civilian Surgical Simulation Elements

Live

Virtual

Constructive

VR/Game Tech
Game Technologies

3D Engine
GUI
Physical Models
Game Tech Core
Network
Persist ence
AI

Game
Tech Core
Training Technology Options

Human | Animal | Box Trainer

Part Task | Mannequin | VR/Game Tech
<table>
<thead>
<tr>
<th>Human</th>
<th>Animal</th>
<th>Box Trainer</th>
<th>Mannequin</th>
<th>Simulation</th>
<th>VR/Game</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn on humans:</td>
<td>Learn on animals:</td>
<td>Learn on organs in a box:</td>
<td>Learn on a physical replica:</td>
<td>Learn on an animated machine:</td>
<td>Learn on computer images:</td>
</tr>
<tr>
<td>Living patients, the newly</td>
<td>Living and newly dead pigs, cats</td>
<td>Human-shaped box contains organs,</td>
<td>A full-body device with synthetic</td>
<td>Includes computer, hydraulics,</td>
<td>Mathematical models, visual</td>
</tr>
<tr>
<td>dead, and cadavers</td>
<td>and others</td>
<td>tissue, or test devices</td>
<td>skin, organs, and fluids</td>
<td>pneumatics, and electrical</td>
<td>images, sounds, and some tactile</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>responses</td>
<td>feedback</td>
</tr>
<tr>
<td>Advantage Exact Replica,</td>
<td>Advantage Similarities,</td>
<td>Advantage Availability,</td>
<td>Advantage Human Shape,</td>
<td>Advantage Rich Experience, Multi-</td>
<td>Advantage Rich Experience,</td>
</tr>
<tr>
<td>Existing OR</td>
<td>Availability</td>
<td>Convenience, Human Shape</td>
<td>Logistics</td>
<td>Function, Programmable</td>
<td>Flexibility, Low Cost</td>
</tr>
<tr>
<td>Disadvantage Scarcity,</td>
<td>Disadvantage Anatomy,</td>
<td>Disadvantage Not Alive,</td>
<td>Disadvantage Static, Lacks</td>
<td>Disadvantage High Cost, Complexity</td>
<td>Disadvantage Screen-barrier,</td>
</tr>
<tr>
<td>Single Use, Ethical Issues</td>
<td>Single Use, Social Mores</td>
<td>Single Use, Animal Organs</td>
<td>Realism</td>
<td></td>
<td>Non-tactile</td>
</tr>
<tr>
<td>Examples Cadavers</td>
<td>Examples Porcine Labs</td>
<td>Examples MIC-Trainer</td>
<td>Examples CPR Annie</td>
<td>Examples Sim One HPS</td>
<td>Examples MIST-VR dV-Trainer</td>
</tr>
<tr>
<td>Live Patients</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Communication Tools are Generational
Motivation
Medical Education – Explosion of Information

• Medical procedures are becoming more numerous and more complex – medical knowledge has “hypertrophied” (Cooke, 2006)

• Training residents to a common level of knowledge and competence is already impossible (Satava, 2008)
“The Perfect Storm” (Murphy, 2007)

- **Risk** to patient health. (McDougall, 2007)
- **Ethics** of practicing on patients. (Satava, 2004; Murphy, 2007)
- **Cost** is a barrier to training. (Bridges, 1999)
- **Insurance** coverage of educational actions. (Satava, 2004)
- **Working hour limits.** (Satava, 2004)
- **Availability** of training opportunities. (Birden, 2007; Davis, 1999)
- **Access to training.** (Dunkin, 2007; Spitzer, 1997)
- **Complexity** of modern surgery. (McDougall, 2007)
- **Volume** of unique procedures. (Reznick & MacRae, 2006)
- **Proficiency-based** Medicine. (Murray, 2005)
- **Quality** of technology. (Murphy, 2007)
- **Expectations** around computer technologies. (Murphy, 2007)
- **Acceptance** of technology. (Ziv, 2003)
- **Learning from Mistakes.** (Ziv, 2005)
Objectives for Simulation/GameTech

• Objective 1: Lower Cost
• Objective 2: Better Access to Symptoms/Cases
• Objective 3: Reduced Training Time
• Objective 4: Reduced Errors

Similar Motivations for Military, Industrial, and Medical Training
Objective 1: Lower Cost

- Surgery as a teaching event consumes resources that could generate additional revenue. (Bridges & Diamond 1999)
  - Accumulates to 186 hours over a 4 year residency
  - Estimate operating room costs at $257.40 per hour.
  - Adds $47,970 to the cost of a medical education.

- Alt: Adds $186,363 to $279,545 during four year residency
  - US operating room $1,500 per hour (Frost & Sullivan, 2004)
  - Swedish operating room $1,000 per hour (Hyltander, 2003)
Objective 2: Better Access

- “The traditional Halstedian apprenticeship model of ‘see one, do one, teach one’ is no longer adequate to train surgeons
- Good laparoscopic skills cannot be developed by merely watching an expert.
- Laparoscopic proficiency is only realized after sufficient practice in the minimally invasive environment.” (Pearson et al, 2002)

- **Learning begins with “do one”** (Jordan et al, 2001; Gallagher et al, 2001b; Madan & Frantzides, 2007).
Objective 3: Reduced Time

• Both MIST-VR and GI-Mentor differentiate experienced from inexperienced users based on their performance scores with the simulator (Adamsen et al, 2005)

• MIST-VR simulator could determine which students will never achieve proficiency and should be dropped from a training program (Gallagher et al, 2004)

• Students trained in VR are 29% faster at performing laparoscopic surgeries and make up to five times fewer mistakes (Enochsson et al, 2004; and Seymour, 2002)

• Non-VR trained students are nine times more likely to fail to make progress in their performance than those who use VR in their training (Seymour, 2002)
Objective 4: Reduced Errors

- “There is no excuse for the surgeon to learn on the patient.” (William J. Mayo, 1927).

- Medical error is responsible for between 44,000 and 98,000 deaths per year (IOM, 1999).

- Laparoscopic surgery has an error rate that is three times higher than that of open surgery. Error rate has not been decreasing over an eight year period as surgeons become more experienced (Huang et al, 2005).

- In laparoscopy, observation does little to convey the skills that must be mastered. Only actual practice has been effective at this (Jordan et al, 2001; Gallagher et al, 2001b; Madan & Frantzides, 2007).

- VR systems are one tool that can improve the performance of surgeons because they become familiar with the appearance of organs and tissue on a two dimensional computer monitor (Huang et al, 2005).
Misleading Assumptions on Traditional Methods

- **Assumption 1: Didactic Education is Effective**
  - Though surgeons or residents may learn new information during educational lectures, they do not incorporate it into their practice. It has no impact on their actions in delivering medicine. (Davis et al 1995 & 1999; Weller et al 2005)

- **Assumption 2: Sufficient Access to Faculty and Patients is Possible**
  - Availability of faculty is a major limitation in medical education (Dunkin et al, 2007; Satava, 2008)
  - Many studies assume adequate access a priori (Gerson & Van Dam, 2003)

- **Assumption 3: Practicing on Live Patients is Acceptable**
  - Medical schools, faculty, and residents are finding new restrictions on the type and amount of training that can be conducted with a live patient (Murphy et al, 2007; Murray et al, 2005; Satava, 2004a; Ziv et al, 2005).
VR & Game Tech
Game Technologies

3D Engine

GUI

Physical Models

Game Tech Core

Network

AI

Persistence
Modeling the World

Hard Objects
- tanks, helos, ships

Human Body
- living tissue

Fluid Dynamics
- water, air flow

Hard Objects are Easy, Soft Objects are Hard
Focusing Outside vs Inside
Surgical Scene Generation

Geometry
• Complex
• Non-linear
• Non-uniform

Appearance
• Layered
• Translucent
• Dense

Dynamics
• Elasticity
• Nerve movement
• Blood flow
Modeling Approaches

- **None**: Omit Feature and Behavior from the Simulation
- **Geometry**: Size and placement of organ
- **Stochastic**: Probability of Injury, Mean Time Between Failure
- **Logical**: Tissue Properties, Flow Rates
- **Physics**: Force, Mass, Friction, Cellular behavior
- **Artificial Intelligence**: Human Decision & Perception
Heart Surgery: Simulation + Animation
Second Life ED – a physician & staff trainer

- Real Data
- Decision Making
- Real Time
- Collaborate
- Group Practice
Physical Modeling Cycle

1. Move
2. Sense
3. Communicate
4. Engage

Start Cycle Here

From *Military Simulation and Serious Games*, Roger Smith
Simulation Software Design Pattern

- Synthetic Environment
- Models
- User Interfaces
- Translators

Data Management

- Simulation Management
- Time Management
- Event Management
- Object Management
- Operating System
- Distribution Management
- Hardware
- Network

From *Military Simulation and Serious Games*, Roger Smith
Components of a Surgical Simulator (Harders, 2008)

- Fluid Simulation
- 3D Model Generation
- Vascular Structures
- Bleeding Simulation
- Tissue Cutting
- Tissue Parameters
- Tissue Deformation
- Organ Texturing
- Collision Detection
- Haptic Interface
- Clinical Expertise
- Immersive OR
Reference Books


References (1)

References (2)

References (3)


