From the Simulation Development and Cognitive Science Lab of Pennsylvania State College of Medicine at the Milton S. Hershey Medical Center

This page contains a listing of available simulators of many types. It was intended for those who are researching simulators for purchase and for those who like to keep abreast with the latest technological developments in medical simulation. This list identifies many types of simulators, including computer screen simulations, instructor and model driven simulators, virtual reality simulators and task specific models. The following is a partial list of each style of simulator. They are listed in alphabetical order. Please note that simulation nomenclature is not standardized yet. These terms may differ from site to site, and between manufacturers.

Model-Driven Simulators

- Emergency Care Simulator -Medical Education Technologies, Inc
- Human Patient Simulator - Medical Education Technologies, Inc
- PediaSim - Medical Education Technologies, Inc
- Sydney Perfusion Simulator - Manbit Technologies

Instructor-Driven Simulators

- AirMan -Laerdal
- Code Blue III - Gaumard
- Noelle Obstetric Simulator - Gaumard
- PatSim-1
- SIMA -Math-Tech
- SimMan - Laerdal

Virtual Reality (VR) / Haptic Feedback Trainers

- AccuTouch Endoscopy Simulator - Immersion Medical
- AccuTouch Endovascular Simulator - Immersion Medical
- CathSim Intravenous Training System - Immersion Medical
- Endotower - Verefi Technologies
- ENT Surgical Simulator - Lockheed Martin Tactical Defense Systems
- GI Mentor - Simbionix
- Key Surgical Activities - Mentice Medical
- Lap Mentor - Simbionix
- Minimally Invasive Surgical Trainer - Mentice Medical
- PERC Mentor - Simbionix
- Procedicus Virtual Arthroscopy - Mentice Medical
- UltraSim Ultrasound Training Simulator- MedSim
- Uro Mentor - Simbionix

Computer Program Simulations

- A-Ware - NEC
- ACLS Simulator - AneSoft
- Anesthesia Simulator Consultant (ASC) - AneSoft
- Bioterrorism Simulator - AneSoft
- Blood Gases - Mad Scientist Software
- Body Simulation - Advanced Simulation Corporation
- Cardiac Arrest - Mad Scientist Software
- Chest Pain - Mad Scientist Software
- Code Team - Mad Scientist Software

Critical Care Simulator - AneSoft
CritiControl - NEC SIM-series
Dynamics Pipeline - MusculoGraphics
Gas Man - Med Man Simulations
Generic Knee Model - MusculoGraphics
Hemodynamics Simulator - AneSoft
MicroEKG - Mad Scientist Software
PhysioLogical - Mark Colson
Pulmonary Arterial Catheterisation Simulator - Manbit Technologies
ResusSim Inhospital -Sophus
ResusSim Prehospital -Sophus
Sedation Simulator - AneSoft
Simbryo - Stanford University SUMMIT
SIMM - MusculoGraphics
Trauma One - Mad Scientist Software
Virtual Anesthesia Machine -University of Florida

Task Specific Models and Manufacturers

Cardiology Patient Simulator (Harvey)-Center for Research in Medical Simulation
CPRView - Michigan Instruments
Dexter
Hernia Training Model - Simulab
SimuView Surgical Trainer - Simulab
Torso Trainer - Simulab
Tower Trainer - Simulab
Training and Test Lung - Michigan Instruments
Trauma Man - Simulab

Options List

physical body - Is the user interacting with a physical object (manikin body or part of a body) representing relevant patient anatomy?
automatic responses - Does the simulator autonomously respond (give immediate feedback) to basic interventions performed by the user, with no instructor input?
performance feedback - Can the simulator itself evaluate performance and give feedback to the user after the session without an instructor present?
independent learning - Can a user work through a module without an instructor present?

A Typology of Simulators for Medical Education

by Gary Meller MD, MBA, FACP (Reprinted from: Journal of Digital Imaging, August 1997)

The field of medical simulation is growing rapidly. Early simulators focused on patients and allowed the physician to practice on this patient. Other types of educational simulators have focused on diseases, and the response to clinical intervention. As computer technology becomes more powerful, simulators will be developed which present complex, interactive, and lifelike experiences that assist the process of medical education and the training of residents. We developed a comprehensive typology of medical simulation interactions which facilitates the development of realistic simulators.

The development of a real-time simulator for teaching ultrasound techniques and interpretation was accomplished by our group. The proposed typology is based on requirements proposed by users. This typology should assist other groups developing simulators for medical education and training. The presentation will elaborate the model, and the history of simulator development. We will also describe the development of the ultrasound simulator.

<u>The analytic framework</u>: we examined and discarded several methods of classifying types of educational simulators. The most useful typology incorporates the elements of the clinical experience, and describes how these elements interact with the user. For our purposes, we use four elements which can be represented as four "P's."

<u>The elements</u> of the analysis include:

P1 = the patient and/or their disease process
P2 = the procedure, diagnostic test, or equipment being used.
P3 = the physician or paraprofessional
P4 = the professor or expert practitioner
p = passive element
a = active element
I = interactive element

Each element of the simulator can be either passive, active, or interactive. A passive element is usually provided to enhance the setting or "realism" of the simulator. Active elements change during the simulation in a programmed way. These elements enhance the simulation, and can provoke responses from the student. Interactive elements change in response to actions taken by the student or by any other element of the simulation. Any simulated element can be substituted for a real one. In most simulations the (P3) element is "real" and represents the student. There are some situations where the physician would be simulated, as in an expert system. The typology leads to classifications which have programming implications. These elements allow the development of a pattern language for simulator development which is reproducible and consistent across many models. Currently the specific data for each simulator element must be encoded in a database or program. We envision a time when multiple simulators may share the same data structures, thereby eliminating expensive data collection and programming costs.

The four "P" types allow the developer to assess how realitistic the simulation must be in order to achieve it's educational goals. This process should be useful to other teams developing training simulators, expert systems, and educational models in the field of medical diagnostic equipment.

The typology focuses our attention specifically on the training environment, and uses the traditional environment to create an educational format for the future. We can also estimate the computational requirements for both interactive processes and passive data. We will give examples of some common types of simulators later in the paper.

<u>History of Medical Simulation</u>: the first medical simulators were simple models of human patients. From antiquity, these representations in clay and stone were used to demonstrate clinical features of disease states and their effects on humans. Models have been found from many cultures and continents. These models have been used in some cultures as a "diagnostic" instrument, allowing women to consult male physicians while maintaining social laws of modesty. Models are used today to help students learn the anatomy of the musculoskeletal system and organ systems.

Active models which attempt to reproduce living anatomy or physiology are recent developments. The famous “Harvey” mannikin was developed at the University of Miami and is able to recreate many of the physical findings of the cardiology examination, including palpation, auscultation, and electrocardiography. More recently, interactive models have been developed which respond to actions taken by a student or physician. Until recently, these simulations were two dimensional computer programs which acted more like a textbook than a patient. Computer simulations have the advantage of allowing a student to make judgements, and also to make errors. The process of iterative learning through assessment, evaluation, decision making, and error correction creates a much stronger learning environment than passive instruction.

Simulators have be proposed as an ideal tool for assessment of students for clinical skills. Programmed patients and simulated clinical situations, including mock disaster drills, have been used extensively for education and evaluation. These “lifelike” simulations are expensive, and lack reproducibility. A fully functional “3Pi” simulator would be the most specific tool available for teaching and measurement of clinical skills. Such a simulator meets the goals of an objective and standardized examination for clinical competence. This system is superior to examinations which use "standard patients" because it permits the quantitative measurement of competence, as well as reproducing the same objective findings.

The "classroom of the future" will probably contain several kinds of simulators, in addition to textual and visual learning tools. This educational environment will allow students to enter the clinical years better prepared, and with a higher skill level. For the advanced student or postgraduate, we will have a more concise and comprehensive method of retraining, or incorporating new clinical procedures into their skill set. This will assist the process of credentialling and competency evaluation which is a major task for regulatory bodies and medical institutions. The classroom of the future can form the basis of a clinical skills unit for continuing education of medical personnel. Similar to the use of periodic flight training for airline pilots, this unit will assist practitioners throughout their career. The simulator will be more than a "living" textbook, it will be a part of the practice of medicine. The simulator environment will be a standard platform for curriculum development in institutions of medical education.

<u>Use of Simulation in Ultrasound Education</u>: ultrasound education has followed a typical historical pattern, even though the science and practice of sonography is less than thirty years old. Initially, most teaching programs in ultrasound followed a traditional apprenticeship model of “see one, do one, teach one.” These programs were hospital based, usually associated with innovative schools and institutions. As the field developed, many programs developed an academic base, with early exposure to clinical patients. In the recent past, programs have expanded their academic offerings. This has often led to a decrease in clinical time because of financial and personnel constraints. Using the ultrasound educational simulator, clinical experience can begin in the early stages of ultrasound education. This allows academic programs to combine classroom work with early clinical exposure. New programs have been developed to reach out to practitioners in the field. Simulator based education is ideally suited for incorporation in distance learning programs and continuing medical education.

For an educational simulator to achieve the level of clinical realism necessary for medical learning, it must overcome the limitations of “virtual reality." Many virtual environments today are limited to cartoon-like images. This level of simplification will have to be overcome. The ultrasound simulator uses real scans to overcome this limitation. Adding freedom of movement along with random acimages, the UltraSim® allows life-like scanning techniques. Machine controls and operator settings function in real time, allowing the student to make mistakes, and correct them.

Education applications of simulation can be used for pre-clinical teaching. Simulators can also be used to teach the function of diagnostic instruments. Students can learn “knobology,” sonographic anatomy and eye-hand coordination. Once the student achieves the basic level of skills required, they progress to more advanced educational objectives. In anatomy the student learns not only basic structure, appearance, and pattern recognition, but also the elusive "range of normal variation" which makes human beings both variable and interesting. The student can proceed to the identification of abnormal pathology. For advanced education and post-graduate students, simulators allow the learning of specialized techniques which include invasive examinations, biopsies, catheter placemment, etc.

Students entering clinical rotations have varying levels of knowledge about clinical material. Using the simulator, the professor can assess pre-clinical competence. The simulator can assist in the measurement of progress during clinical rotations. This technology also lends itself to identifying strengths and weaknesses of the individual, and preparing customized remedial programs. The goal of clinical education has been expressed as translating "know-how" into "knows-how." The simulator can also assess the student's ability to "show-how" well these skills have been learned.

Examples of Simulator Types: to understand how the typology works, we will look at some samples. The most common setting for clinical education occurs when a team "makes rounds" on patients in a clinic or hospital. This setting includes the patient, an attending physician, and one or more students. To fully simulate this interaction (i.e. to recreate it) we would have to develop of (P1P2P3P4) or "Four Pi" simulator. Each of these elements is fully interactive. Such a simulator would constitute an expert system for clinical interactions.

P (One P) Simulation: a"One P" simulator includes anatomical models such as the "Ressuci" dolls which are used for training in cardio pulmonary resuscitation. These mannequins can be passive, active, or interactive based on the level of training. Simple mouth to mouth breathing and chest compression is taught on a passive simulator (P1 p) . More advanced models may simulate wounds, or the result of wounds such as a pneumothorax. If the wound simulated bleeding, or air movement, then it would be a (P1a) simulator.

PP (Two P) Simulator: advanced CPR with cardiac life support is taught on a mannequin combined with a computer program which simulates the electrocardiogram. In this case, both the patient and the diagnostic test are being simulated. This is a (P1 a P2 a) simulator. If the electrocardiographic portion of the simulator has been programmed to respond to the administration of medications, or electrocardioversion, then this would be a (P1 a P2 i) simulator.

PPP (Three P) Simulator: the UltraSim® ultrasound educational simulator is an example of a "Three P" simulator. The UltraSim® includes a mannequin and software which simulates the patient interactively. The machine looks and feels like a standard ultrasound unit, although it has no ultrasound capabilities. In addition, in the expert mode, the UltraSim® can simulate the interaction between a student and a professor. Using a three dimensional positioning program, the unit will guide the student in the skills necessary to obtain accurate ultrasound scans. Thus the UltraSim® is a (P1 I P2 I P4 I) simulator.

PPPP (Four P) Expert systems: although the need for Four P simulators is rare. The analysis shows that such a machine would be an expert system, with all elements of the clinical interaction represented. From a theoretical point of view, this machine could be used to study the economic and cost-benefit aspects of the health care process. It could also be used to assess the functioning of other simulators or diagnostic tools. Such a simulator could be considered the "dream machine" of an HMO administrator, "no patients, no doctors."

Medical Applications of haptic (touch feedback) simulators
(from Novint commercial website)

The sense of touch is crucial for medical training. Many diagnostic, surgical and interventional procedures require that physicians train and utilize their sense of touch. Effective medical training utilizing computers, therefore, has not been feasible before now. Novint's technology and medical products add this missing component to computer-based medical training. It is Novint's goal to become the dominant player in the medical training arena, and we see a day when all doctors will learn many of their skills and procedures using our software. Ultimately we will have simulators that train in many different fields, will provide the "gold standard" for certification and will sell into products for training seminars, conventions, physician's offices, and hospitals as well medical schools.

In conjunction with the Harvard School of Dental Medicine, Novint has developed an advanced prototype of a dental training product. Our VoxelNotepad product, originally funded by the petroleum industry, is used for interacting with medical imagery such as that derived from MRI, CT and 3D Ultrasound devices. Finally, we have developed proof of concept versions of touch-enabled medical applications such as a needle insertion trainer.

<u>Dental Training</u>: the Virtual Reality Dental Training System (VRDTS) has been developed in collaboration with and partially funded by the Harvard School of Dental Medicine. Dental students currently use artificial teeth and jaws, along with real dental instruments, to practice cavity preparation and other procedures. These plastic models, however, lack the level of detail and material properties needed to accurately simulate real teeth and procedures. For example, real life complications, such as bleeding, and many common procedures, such as tooth extraction, cannot be simulated with these plastic training systems. Current training procedures, therefore, require that dental students gain a significant portion of their required experience while practicing on live patients. This is obviously less than optimal. Furthermore, utilizing classical, visual-only, computer simulations is not acceptable – a significant part of the student's learning is tactile in nature. A "hands-on" curriculum is literally required. Novint's VRDTS application, however, provides the tactile involvement needed for dental training. Moreover, VRDTS offers training benefits that are not possible with either plastic models or live patients. The student, for example, can repeat and playback procedures many times, precisely measure and quantify their results, and work at different size scales.

VRDTS -- Cavity Preparation Trainer

Novint has developed an initial version of a Cavity Preparation (CP) procedure trainer, wherein the student diagnoses, removes and repairs an occlusal cavity. The user has 4 instruments simulated in the system – an explorer, a drill (burr), a carrier, and a carver. This application is envisioned as the first in a series of dental trainers. We have developed the core (i.e., volumetric) technology that allows realistic touch-enabled simulation of the multiple tissues found in teeth and the interaction of virtual tools with these tissues. We also envision using this technology in applications that can be sold to individual dental practitioners as education and procedure aids. For example, the same technology used in VRDTS could be used to help automate the generation of dental implants. Novint is currently actively pursuing funding in order to fully develop the VRDTS system.

Medical Diagnosis, Planning, and Visualization: Novint's voxelNotepad (VNP) application allows 3D medical data to be felt as well as viewed in real time. Novint began development of VNP in 1999 under funding from the petroleum industry. Novint integrated the PHANTOM haptic interface with a Windows based PC system and advanced volumetric software to create the first 3D touch-enabled environment for medical data analysis and diagnosis. There has been a growing disconnect between the computing needs of radiologists and surgeons and the capabilities of their computer tools. MRI, CT and 3D Ultrasound Scan data is inherently 3 dimensional and growing more detailed and complex all the time. Yet the human computer interface typically used for interpreting this data – comprised of the mouse, keyboard and video display terminal – is 2 dimensional and (many would argue) less than intuitive. Novint's VNP software makes it possible to interpret MRI, CT, and 3D ultrasound data completely in 3D – directly and intuitively. Using VNP, the user can set the visual and touch properties of the medical data interactively, enabling the haptic and visual highlighting of areas of interest (such as a tumor or arterial calcification). No longer must a radiologist or surgeon "guess" when trying to determine the depth or extent of 3D structures on 2D media such as film or traditional computer displays. We are also exploring intraoperative utilization of the system for real time uses of the technology during surgery.

Needle Insertion: there are a wide range of needle insertion procedures for which it is not currently possible to adequately train medical students and residents. These include anesthetic blocks (epidural, celiac plexus, etc), obstetric (amniocentesis, cordocentesis, etc), orthopedic (injection of joint lubricants) – this is but a small portion of a very long list. Needle insertion by its very nature is based on and requires touch feedback – it is well suited to our e-Touch technology. In addition, physicians, nurses and other medical personnel all require training in various needle procedures. Training in all of these procedures is fundamentally similar – it is only the anatomical region of interest and the goals of the procedure that vary. Because of these factors, Novint envisions a family of "needle insertion" trainers. Novint's needle insertion simulator allows a user to feel what it is like to take a needle biopsy. The user can feel the needle push through various layers, including the skull.

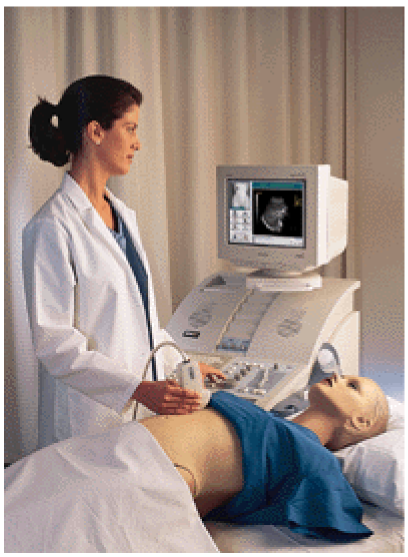
As in other medical procedures that require the sense of touch, current needle insertion training techniques are inadequate. Mannequins are only somewhat realistic and difficult to reuse, cadavers are difficult to come by and similarly unrealistic, and animals are usually not applicable or easily obtained. Residents are trained via an apprenticeship, under the watchful eye of an experienced surgeon or anesthesiologist. The novice often performs 50 procedures before they are deemed ready, and this is for each of a number of different procedures their discipline might require them to perform. This approach has costs (the downtime of the experienced surgeon, the cultural stigma against animal experimentation) and risks (that a novice surgeon might make a mistake when practicing on a human patient). And of equal significance is that neither of these procedures provides for quantifiable measurement of the novice's abilities. Novint's technology allows us to get around the limitations of current training approaches and address the widespread need for adequate needle insertion training.

Medical Simulation Center at the Rhode Island Hospital

About Medical Simulation: what is it? Medical simulation is the set-up, monitoring and review of a controlled medical event, designed to educate health care providers and broaden their experience with critical situations. Because simulations are completely staged, participants are able to make mistakes and learn from them without any risk to patients, and then use what they have learned in real-life situations.

The future of medical education: the rapid rate of information growth, increased demands on physician educators, and patient safety concerns have created a challenge to the present model of hands-on training for health care personnel. High fidelity medical simulation offers numerous benefits for patients, trainees, as well as educators, and is becoming an integral tool in the future of medical education.

High technology means realistic situations. Medical simulation technology allows for realistic clinical scenarios using life-sized computerized patient manikins that are able to respond in real-time to a variety of clinical interventions and pharmacologic agents. This type of technology offers medical educators a new way to control situational learning. Some highlights: The computer-driven manikins range from $30,000 to $200,000 and are capable of verbal communication, accurate representation of common physical exam findings (airway compromise, lung and cardiac sounds, pulses etc), and physiologic responses to drug and treatment interventions. Realistic representations of actual treatment settings allow simulation participants to suspend disbelief and immerse themselves in the training exercise. Participants involved in the simulation may include physicians, nurses, allied health care personnel or multidisciplinary teams.



A history of success: simulation training is well established in other complex, high-risk industries such as aviation, nuclear power, and the military, all of which are regarded as high reliability organizations. The use of realistic high fidelity interactive patient simulators was pioneered in anesthesia in the mid-1980s. However, only recently has simulation technology come into more widespread use, and its full potential for medical education has not yet been realized. The goal of the Rhode Island Hospital Medical Simulation Center is to actualize this potential and create a learning environment which fosters the development of superior clinical skills without risk to patients.