2010 North American Summer School on Surgical Robotics and Simulation

http://brl.ee.washington.edu/SummerSchool2010/

Trip Report

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The North American summer school on surgical robotics and simulation was organised for 50 doctoral students to attend a 5 day series of 90 minute tutorial lectures and hands-on labs. The week's lectures and labs are described below to give an overview of the event.

Dates: 23-27 August, 2010
Location: Seattle Washington.

A brief summary of my opinions formed or backed up during the week is given first with more details following in subsequent pages. A poster presented at the event is shown on the final page of this document.

Overview

It was said during the week that "Surgery is 25% technique and 75% judgment" and I feel that both of these skills should be trained and assessed in full procedure surgical training simulations. There were many methods of assessing skills discussed during the week but there seems to be no one method that can be used as an outright method of assessment. Cognitive load could become a suitable metric as technology to monitor this progress.

Virtual simulations offer the opportunity to train the worst case scenarios as aircraft simulations have demonstrated. In laparoscopic surgery this could involve simulating a standard procedure and then introducing a bleed at another location, which must be fixed before the standard procedure is resumed.

Background noise and a method of increasing the stress levels of a trainee, for example someone asking what the trainee is doing and requiring an answer, may help to make a training simulation more realistic and after training make a procedure more second nature to the trainee. It appears that introduction of the distractions of the operating room would be a simple but effective way of increasing the fidelity of a training procedure.

Simulations should provide no go areas, reacting to incorrect manipulation and not rely on a highly structured set of must do procedures (order may vary a little). This will enable procedure variability and not limit the use of a simulator to one training facility.

Currently simulations are hard to compare and validation varies greatly between simulations. It would be advantageous but possibly unrealistic to change this.

Force and deformation models need to greatly improve for realistic real time simulation which is necessary for accurate simulation. When this is achieved these same models can also be used in the field of medical robotics. At this point the fields may merge.

Hands on sessions

During the course we had the opportunity to try multiple surgical education simulation platforms for the training of minimally invasive intra abdominal surgery. In the first hands on day we had the opportunity to test the fidelity of the simulation platforms which varied significantly. Box trainers offered the most realistic feeling as real objects were manipulated. However, although the blocks in the peg transfer task felt real (they were) the blocks didn't closely match real anatomical objects. A simulated intestinal structure with which we trained to pass between tools did more closely resemble that of a real pig and I assume a human.

The virtual simulations offered sub standard physics simulation. A bowel simulation didn't react in a realistic manner to the tools and was either clamped on or off, no slip in the tool occurred. No force feedback was given by this model of simulator and consultation with the attending trainer confirmed that the physics simulation was well below the necessary fidelity for correct simulation and therefore there was a risk of undesirable negative training.

To offer a contrast to the MIS procedure we were able to attempt the same two tasks, block passing and two hand passing of intestine, with the daVinci robot from Intuitive and the dvTrainer from Mimic. The wrist actuation of the daVinci coupled with its stereoscopic view and motion scaling made the robot extremely easy and smooth to manipulate and tasks were easy to perform. Tool collision avoidance was not present and as such one wrist could grasp and collide with the other. No force feedback is provided by the robot. The dvTrainer (explained later) lacked the high quality view of the daVinci but offered a lower cost solution for training. The haptic devices did not provide force feedback like the daVinci robot.

On the second hands on day we were able to experience the skills and techniques required to carry out a real minimally invasive procedure and feel the real forces involved whilst in a porcine laboratory. This enabled us to be able to manipulate intestine and test various tools in-vivo. This experience was an invaluable experience to let the predominantly engineering and computer scientist students to experience a real procedure and to envisage what needs to be simulated or improved robotically.

Lectures

The lectures are listed in order of appearance.

Simon DiMaio, Intuitive surgical

Intuitive surgical produce the daVinci Robot which currently sells for 2 million US dollars. They quote their mission as "To use robotics to take surgical precision beyond the limits of the human hand (and eyes, etc.)".

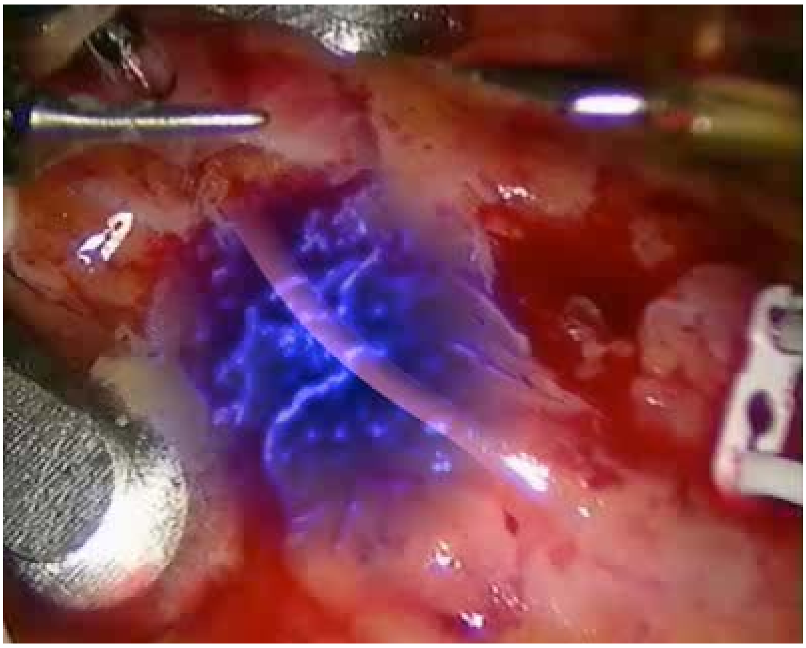
Some of the innovations they are working on are:

- Addition of augmented vision overlaying narrow band imaging images over the RGB images to provide extra information.
- Augmented reality to overlay ultrasound images into the surgeons view
- Adding haptic a tactile feedback to the daVinci. Some people have concern that this would have to be extremely good to not distract users.
- Move toward single port access. The less invasive procedure could help to provide faster healing times.

A PhD student attending the school is researching touchless control of the robots, this would allow the robot to be controlled by a sterile surgeon who would be able to interact with the patient if necessary. Currently the robots master interface cannot be sterile. Disadvantages of this are no haptic feedback could be added and the PhD student reported fatigue of the hands.

Guang Zhong Yang, Imperial College, London

Gave an in depth summary of the medical imaging modalities and how they work. He described automated tracking of the pulmonary valves. This is useful as imaging techniques commonly track a position in space not a moving target such as a contracting valve. It was highlighted how, with realistic models of the pulmonary system an augmented view through walls could be achieved if simulations were accurate enough in real time (See picture).



Yoshinobu Sato, Osaka University

Talked about developing a statistical atlas of anatomy and applications of anatomical modelling and therapy planning using the atlas.

A statistical atlas is a representation constructed through statistical analysis of a large number of training datasets of (surgical) cases. These can represent statistically-derived (or statistically compiled) knowledge of anatomy and pathology.

A statistical atlas could represent

- Organ shape and location (e.g. liver)
- Organ motion (e.g. heart)
- Distribution of lesions (e.g. prostate cancer)
- Distribution of physiological activities (e.g. glucose metabolism)
- Implant selection and positioning for patient anatomy (e.g. hip implant)
- Organ deformation and movement in surgery (e.g. due to posture change, respiration, or surgical operations)

It is required to model anatomical/pathological/clinical phenomenon and knowledge which appear difficult to model analytically to deal with biological variability in a compact way (for example, as a parametric model with small number of parameters). The model can then be used to estimate a specific instance of the model from a patient dataset in a robust and accurate manner or to estimate a complete model from incomplete data.

Greg Hager, Johns Hopkins University

Johns Hopkins University have a rare contract with Intuitive and therefore good but rather secretive access to the daVinci robots API (although they aren't given too much to work with either).

During the talk Greg said

"The average med student has 100-250k of debt by the time they finish." This seemd to be a good motivation for faster training of the student to reduce student debt and the cost of training incurred by the hospital.

There is "no widely used measure of surgical performance."

"New devices such as the da Vinci robot impose new complexities in training."

He then asks what should be measured and compares training to a driving test. Measuring just the ability to drive, move a car (can a surgeon complete a procedure), measuring the speed the driver can get to their destination (speed of completion), and the number of accidents they have on their way (the number of mistakes made), He asked what could be a valid measurement. No Conclusions were made.

"Surgery is 25% technique and 75% judgment", so should simulation measure judgment?

Studies should be, Feasible, Reliable and Valid.

Types of validity are (Darzi 2003)

- Construct validity – does it measure what we want it to measure?
- Content – does it focus on the right aspect (technique vs knowledge)
- Concurrent – does it correlate to an existing gold standard?+
- Face – does it resemble real life?
- Predictive / external – does it predict / generalise to other performance

Introduces the concept of automated data collection. Imperial College Surgical Assessment Device (Darzi et al) uses electromagnetic markers to track a users hands. MIST (Minimally Invasive Surgical Trainer) tracks hands automatically. daVinci collect information for free (if you work with Intuitive). Talk goes on to describe video analysis of daVici video. Segments these into tasks and categorises them. Categorises videos into expert, intermediate and novice classes automatically.

Three ways to recognise skill

- The ability to use ones knowledge effectively and readily in execution or performance
- dexterity or coordination especially in the execution of learned tasks
- A learned power of doing something competently: a developed attitude or ability.

At the end I asked if you can spot the progression can you pick out the people who won't make the grade as surgeons and then tell them before a lot of money is invested to train them fully. No real answer was given. A slide shown by Mika Sinanan shows highlights this question again.

Jeff Berkeley, Mimic Technologies

Presented the dvTrainer for training to use the daVinci robot: A company presentation. Points made for product were

- Frees up the clinical robot for revenue generating procedures
- Speeds up surgeon learning curve
- Does not require access to da Vinci robot ehich is expensive

The simulation provides no force feedback (like the robot) and a stereo view which is of lower quality to the daVinci's. The simulation is produced to train the skills of operation of the robot and how the tool can be manipulated. The simulation of realistic tissue interaction is not simulated. The wires interfered with wrist movement, and the mock clutches didn't work well on the two tested models.

Doug Beighle, simulab

Another company presentation. Biases to mannequins as this is what the company manufacture.

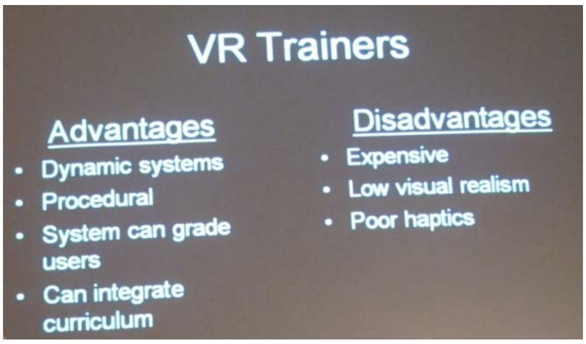
When should simulation be used?

- Procedure is low frequency
- Procedure is high stakes
- Procedure should be second nature

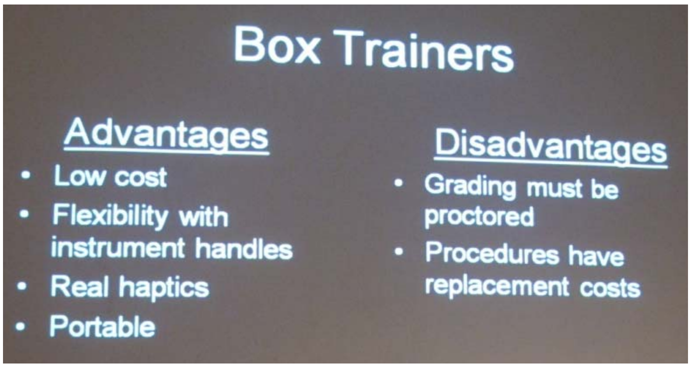
Said "There is no such thing as a standard patient". This presents the question then how does a single mannequin cope with this variability?

Also said "lack of standardized practices and standardized outcomes". This is indicates that medical simulation needs to improve to incorporate this variability in practice. A simulator could therefore not limit the order/methods used to complete an intervention as long as no critical structures are punctured/damaged.

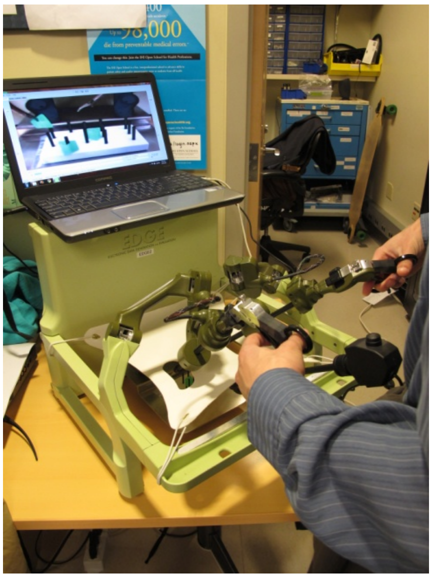
Why VR trainers:



Why box trainers (Doug has a bias toward this method)



This is the EDGE, a tool which although interacts in the real world is virtually tracked so that metrics can be recorded. One recorded metric is tool grip pressure.



During questions, Doug said that he thought virtual training had its place in training where students were trained to perform multiple task/ manage multiple situations at once. Whilst one task should be second nature, a bursting artery may need to be fixed off to the side, then the practitioner would have to resume task one after fixing the distraction.

Ichiro Sakuma, Tokyo University

Main topic of the talk was on electrical stimulation of a Langendorff perfused rabbit heart based on in vivo fluorescence imaging of membrane action potential. Very interesting but not of great value to my medical simulation work.

Paolo Dario, Scuola Superiore Sant'Anna, Pisa

Talked about micro pill robots, again very interesting and a possible solution to the intuitive monopoly on surgical robots but not relevant to my simulation work.

Russ Taylor, Johns Hopkins

Introduces the growing field by highlighting the rapid increase in papers on robotic surgery in the last 10 years.

Amongst other applications for medical robotics, the most interesting to me was the steady hand robot, a human controlled arm which filtered out the human controllers jitter for a more precise eye surgery.

Cone-Beam CT-Guided Surgical Navigation. This was an interesting application using CT images to give 3D image guidance to a needle navigation using the Claron MicronTracker. Work by J.H. Siewerdsen, Johns Hopkins University.

Concluding slide: The bottom line.

- Provide new capabilities that **transcend human limitations** in surgery
- Increase **consistency and quality** of surgical treatments
- Promote **better outcomes** and more **cost-effective** processes in surgical practice

Kevin Cleary, Georgetown University

Topic of talk was using imaging as a bio marker
A bio marker is a characteristic that is objectively measured and evaluated as an indicator of normal biologic processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention.

Normal or disease processes in biological organisms eventually lead to a distinct endpoint. However, by this point it is usually too late to intervene. We need biomarkers which are excellent predictors of endpoints.

Used for :

- Osteoporosis – View bone shape at the hip. The angles of the bones can be used as a good indicator of problems.
- Alzheimer's – Using MRI to spot mild impairment before Alzheimer's can be observed (UCLA by Jorge Barrio and Gary Small)
- Coronary Artery Blockage
- Cardiovascular Disease- Kelly P and Bhatt DL, "Identification of Vulnerable Plaque -The Quest Continues" Journal of Invasive Cardiology 19, Feb 1, 2007

Why? A normal longitudinal clinical trial with a mouse would need 4 miceand one would be killed each week to see the progression of a pathology. The newer and more scientific way is to use one mouse for all four weeks and study its progression over time through the study using imaging techniques.

Gave a good summary of all types of imaging techniques. X-ray, CT, MRI, Ultrasound, nuclear medicine PET and SPECT, combined CT and PET.

Presented an image guided intervention - Lung biopsy in CT suite. Normally guided by images only a 3D representation is make up and markers / trackers placed into the patient. Using this, the practitioner can have a 3D guide to steer the biopsy needle to the correct point. Not entirely successful as of yet as the patient is soft and can move….

Gave a summary from OR2020 - Operating Room of the Future. A multi disciplined meeting. (OR2020.org)

Things that need addressing:

- Standards, standards, standards
- Architecture
- Workflow
- Telecollaboration
- Safety as an overarching theme
- Training must be built in
- Robotics has a role: smaller, cheaper, more capable
- Intraoperative imaging: one size does not fit all
- Surgical informatics: integrated system
- Lots of variability in the system
- Can learn from radiation oncology
- Import of images, archiving of data

Went through the Image-guided Surgery Toolkit IGSTK, which is open source software.

Mika Sinanan, University of Washington

Current Drivers of Surgical Therapy

- **Efficacy**–often but not always the most effective and durable means of correcting structural problems and eliminating regionally confined disease (infection, inflammation, tumor)
- **Safety**–the right treatment for the right patient at the right time –for optimal results
- **Cost**–OR time $10 –30$ *per minute*
- **Efficiency**–essential but limited resource –capital, maintenance, and disposable expenses and FTE costs

Presented figures of support for the daVinci robot in the form of blood loss and recovery times for a daVinci Prostatectomy.

Ability vs. Skill

Ability: capability or aptitude

- Cognitive
- Psychomotor
- Physical
- Perceptual (sensory)

Skill: learned or trained, goal-directed, coordinated activity *developed by training*

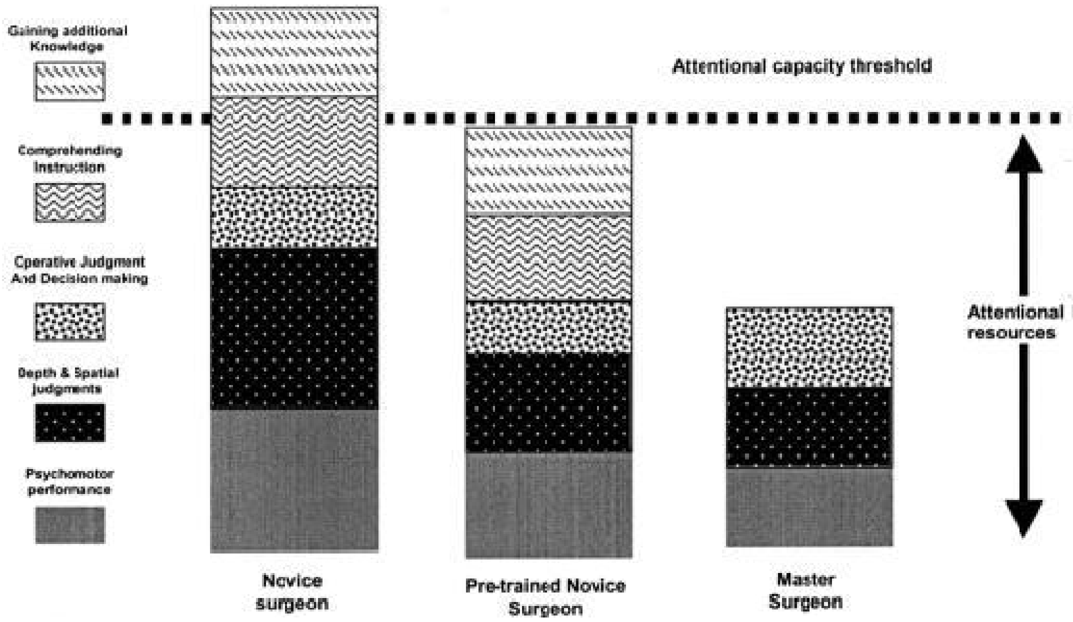
- Intellectual
- Verbal
- Cognitive
- Motor
- Attitude

The goal of training is to maximize to the potential of an individual's abilities – I interpreted this as, fit the right person to the correct job.

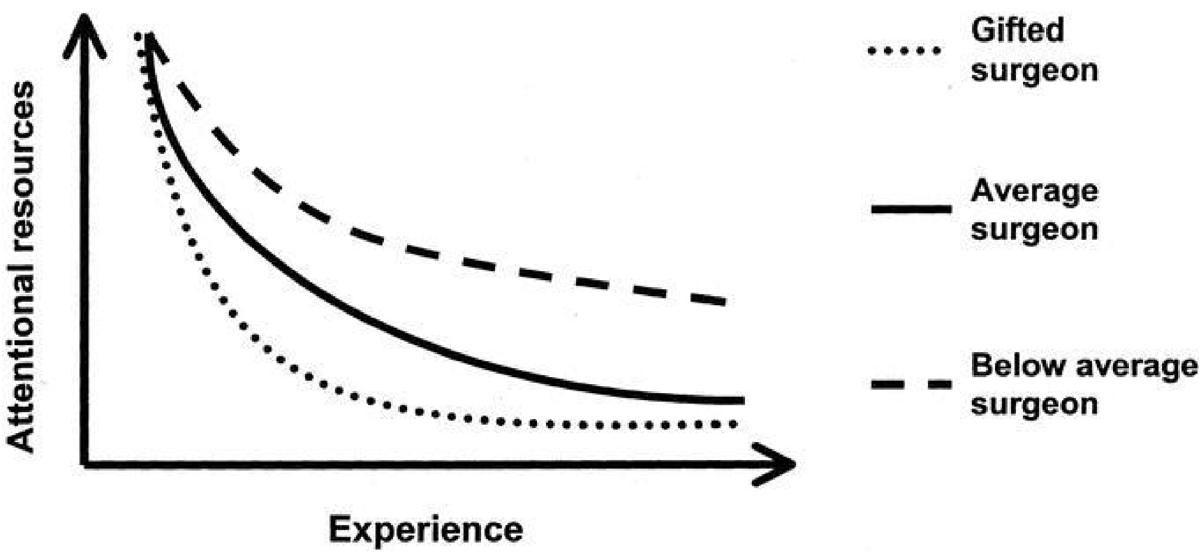
Training and mastery of a skill: Paper - Fitts and Posner, *Human Performance*1967.
The stages of skill acquisition are:
- Cognitive –intellectualized process, familiarization with tools
- Associative –development of motor skills
- Autonomous –smooth performance

There is a need to provide users technical performance and error analysis
- Formative: delivered during training to modify technique
- Summative: delivered at the end of training to assess performance

As the practitioner becomes more competent the cognitive load becomes less. This could be used to differentiate novice from master. Gallagher, Satava, et al.



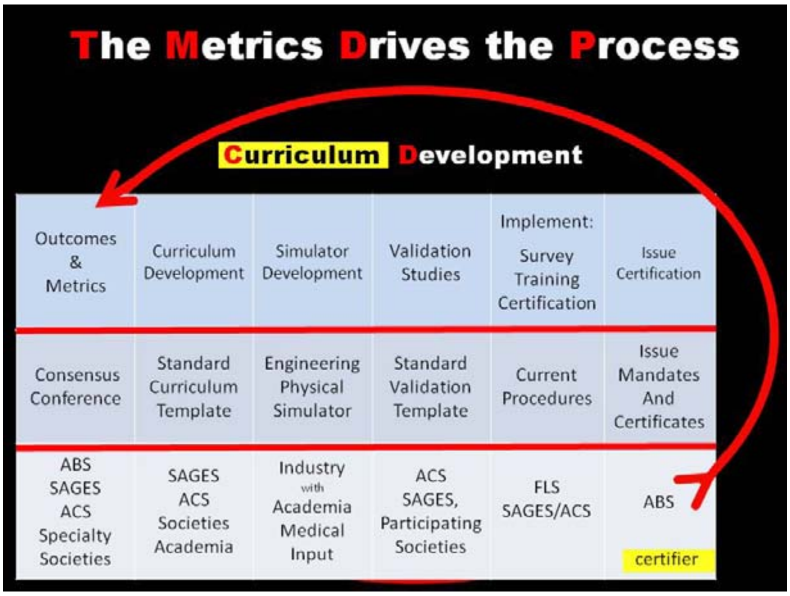
The learning curves of surgeons. Could use this to spot the trend and pick out who is good and who should not become a surgeon?



Dinner Speaker: Rick Satava

Gave more of an inspirational talk rather than talking about too much technology. He played a video on the OR of the future (screen shot) and the battle ground OR.

He emphasised the need for metrics.



Blake Hannaford, University of Washington

Blake gave an informative talk on the basics of force sensing. Presented stress, strain and Hooke’s law and went on to summarise the types of sensors available.

He then went on to present a study of the optimal tissue grasping force which could be used for correct training of laparoscopic training.

Rob Howe, Harvard University

Works on beating heart intracardiac repair. Here the heart is repaired whist it is still beating. Of most interest to me was the catheter robot prototype that can "follow fast cardiac motion"

Tim Salcudean, U. of British Columbia

Presented work which is a continuation of Simon DiMaio's (presented on Monday for intuitive surgical) initial work. This work focuses on needle insertion models and the simulation of needle insertion which could be used for force feedback simulation and planning of needle insertion into deformable tissue. Work focused on prostate brachytherapy.

A few paper I have found on this are :

O.Goksel, S.E.Salcudean, and S.P.DiMaio: "3D Simulation of Needle-Tissue Interaction with Application to Prostate Brachytherapy".
O. Goksel, E. Dehghan, and S.E. Salcudean, "Modeling and Simulation of Flexible Needles", Medical Engineering and Physics, in press doi:10.1016/j.medengphy.2009.07.007
E. Dehghan, X. Wen, R. Zahiri-Azar, M. Marchal and S.E. Salcudean, Needle-Tissue Interaction
Modeling using Ultrasound-based Motion Estimation: Phantom Study, J. Computer Assisted Surgery, 13(5):265-280, 2008.
E. Dehghan, S.E. Salcudean, Needle Insertion Parameter Optimization for Brachytherapy, IEEE Trans. Robotics and Automation, 25(2), pp. 205-315, 2008.

Jacob Rosen, U. California Santa Cruz

Beating heart surgery and small robots to enter the body (like Paolo Dario). Advocates small robotics within the body as the future of medical robotics. Almost revised what had been talked about before...

Howard Chizeck, University of Washington

Teleoperation. Working on high DOF end effectors and looking at how to achieve interoperability between high and low DOF end effectors for robotics. Also looking "high confidence computing and communication security" which describes how to manage the security of teleoperation. For example if the control of a remotely operated surgical robot were to be intercepted it could lead to devastating consequences for the patient.

Accurate simulation of tissue is needed for correct prediction in surgical robotics and simulation. Is a fast type of FEM the way forward?

Haptic feedback can be used to give no go areas during surgery.

Howards long terms goals ,

- Create databases containing models that correlate stress to tissue damage for a number of organs and develop a better understanding of soft tissue biomechanical properties;
- Enhance surgical simulator design to portray more realistic tissue responses during manipulation and provide more detailed evaluations of tissue handling skills.

AR Haptic Training Simulation for Femoral Palpation and Needle Insertion Tim R Coles

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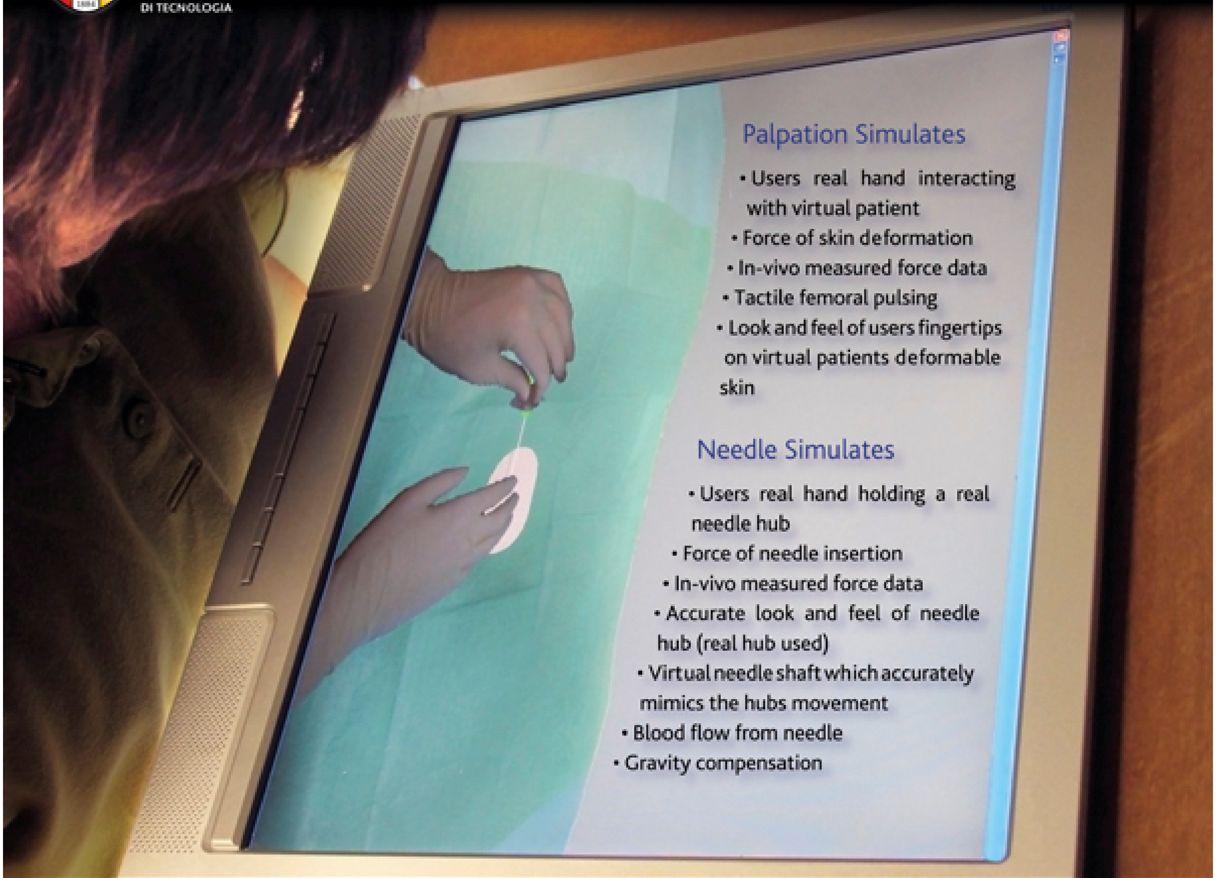

This augmented reality approach for training of the Seldinger technique places the trainees real hands in co-location with a visio-haptic virtual patient. In-vivo measured force and tactile feedback is conveyed to the trainee through three modified commercially available force feedback devices and a custom made tactile end effector. Visual feedback is displayed on an LCD screen and uses two cameras to display the hands and their shadows. Supervised by N.W. John (Bangor) and D.G. Caldwell (IIT). Medical partner D. A Gould (Royal Liverpool University)