Department of Computing Science
University of Alberta

Medical Collaborative Virtual Environments for Training and Data Visualization

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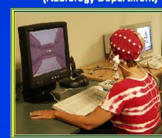
Advanced Man-Machine Interface AMMI Laboratory and Medicine


Collaborative VR Environments for MRI and CT Data Analysis (Radiology Department)


Motion Tracking and Analysis (Glenrose Hospital)


Sensor Fusion (Faculty of Dentistry)


VR and Human Perception

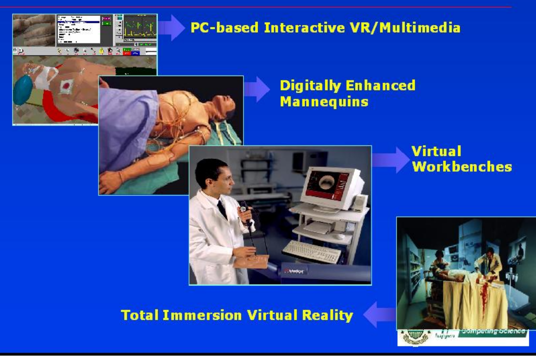

Surgical Trainer Over High-Speed Network (Ophthalmology Department, UofO)


Training Room Using HALO System (TRLabs+HP)

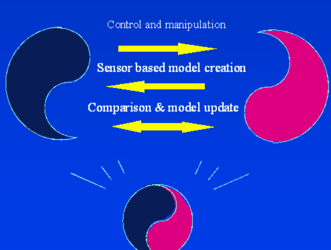
Mandate

- To perform research in new man-machine interfaces allowing computer systems to enhance human abilities by adapting to their needs.
- To develop human centered automation systems.

MULTIPLE TECHNOLOGIES



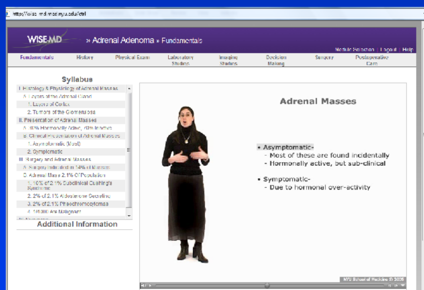
Virtual vs. Real World



Virtual Training System Types

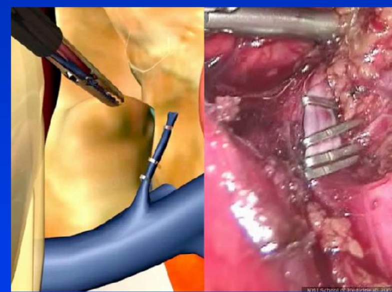
- Functional/Cognitive
- Analog
- Virtual
- Virtual/Analog

Example I: WISE-MD (Functional Type)



http://wise-md.med.nyu.edu/

VR Model and Video of Real Surgery



Example II: Diagnostic Peritoneal Lavage (Analog vs Virtual)

- One of the Core Skills taught in ATLS® to ~ 20,000 students/yr to diagnose presence of blood in abdomen
- Traditionally taught on animal model (pig or goat)
- Mannequin (Traumaman™) recently approved as alternative

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Validation Study

SimPL vs Pig for teaching DPL

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DPL Validation Study Design

- 40 Third Year Medical Students who were all true novices (never done one, never seen one)
- Divided into two groups of twenty
- Initial 30 item Test covering basic knowledge of the procedure, it's indications, interpretation of results and possible complications given prior to any education.

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Pig Group (n=20) Trained to do DPL on a Pig

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Sim Group (n=20) trained to DPL on VR DPL simulator

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Performance on Mannequin

Performance on Mannequin evaluated and scored by two trauma surgeons blinded to initial mode of training.

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DPL Validation Study Design (Cont)

- Final 30 item test given to test knowledge of procedure, indications, and potential complications
- Comfort level, perceived difficulty ,and familiarity with steps reassessed.
- Surgeon evaluators provided assessment of students current ability to perform a DPL if called upon to do so tomorrow following this training

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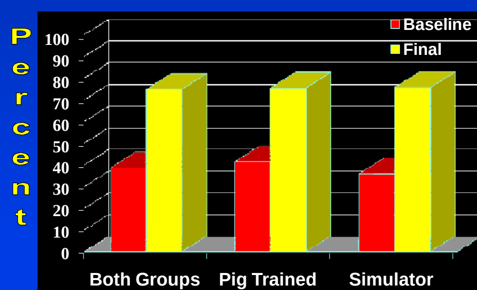
Test of DPL Knowledge Based on a 30 Questions Written Test



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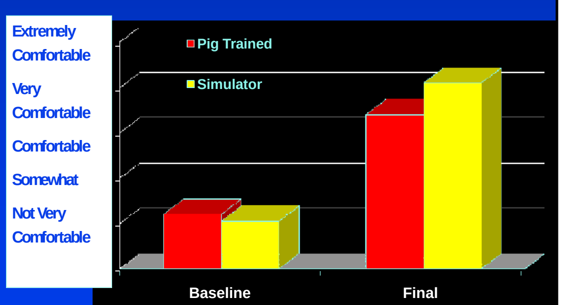
Subjects Perceived Comfort Level Performing DPL



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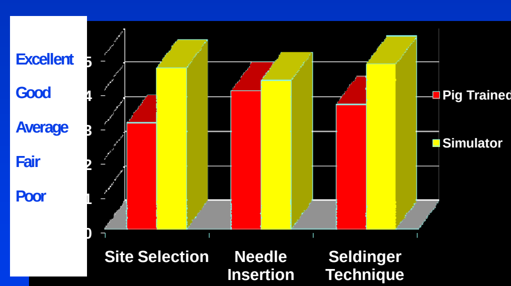
Faculty Evaluation – The Student Performance:



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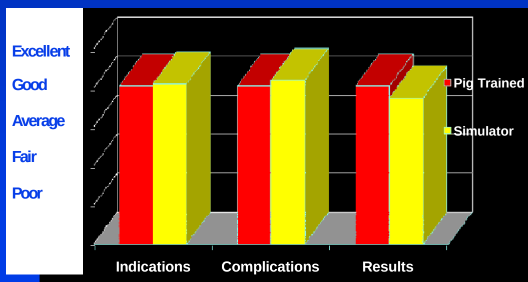
Faculty Evaluation – The Students Ability to Discuss the Procdure



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Faculty Evaluation

N = 20 each group	Pig Trained	Sim Trained
Strongly Agree	3 (15%)	5 (25%)
Agree	9 (45%)	13 (65%)
Neutral	6 (30%)	2 (10%)
Disagree	2 (10%)	0
Strongly Disagree		

If placed in the field tomorrow, I believe this student has the necessary skills to successfully perform a DPL.

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Summary of Results DPL Validation Study

- Knowledge increased significantly in both groups over baseline: Excellent Content Validity
- Students self reported level of comfort increased in both groups but more so in the simulator trained group

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Summary of Results DPL Validation Study – Cont.

- Students who trained on the *SimPL* had significantly increased their performance on site selection and understanding of the Seldinger technique
- Evaluators had greater faith in ability of Simulator trained students to perform procedure after training (90% vs 60%)

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Example II: Hapto-Visual-Audio-Virtual Environments (HAVE)

- The goal of this project is to develop shared hapto-visual-audio-virtual environments (HAVE) with advanced multi-point video conferencing, new display and interface technologies, and distributed latency compensated haptic technologies that will be used for collaborative medical research and training in ophthalmology.
- Financed in part by Canarie Advanced Research Project ARP-20

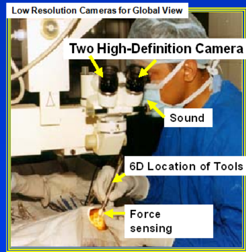
Typical Cataract Surgery

Two things happen during cataract surgery:

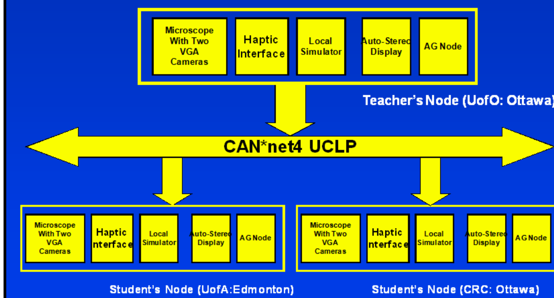
1. The clouded lens is removed
2. A clear artificial lens is implanted

What About the Real World?
(Virtual/Analog)

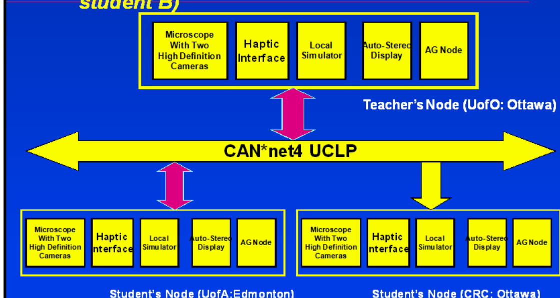
- The digitized modalities must be perfectly synchronized
- Compression should be minimal to avoid miss interpretation
- Digitizing equipment must be operating room compatible



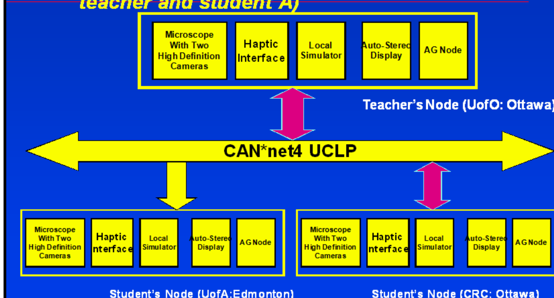
How to Train Ophthalmic Residents Remotely? (teacher to two students)



How to Train Ophthalmic Residents Remotely? (student A to teacher and student B)

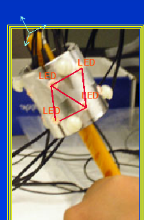


How Do You Train Ophthalmic Residents Remotely? (student B to teacher and student A)



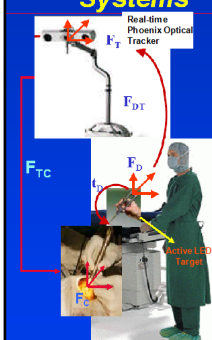
Active Optical Tracking of Surgical Instruments

Real-time Phoenix Optical Tracker



Active Instrument Tracking Target

Optical Trackers Coordinate Systems

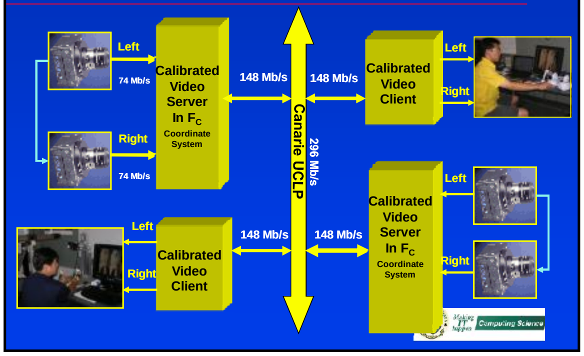


- **The central coordinate system is located at the center of the eye F_C**
- **The tool tip is known in F_D**
- **The tool target is known in F_T**
- **The transformation between the tool target and the sensor is: F_{DT}**

The tool tip t_D can be expressed in the frame of the eye t_C:

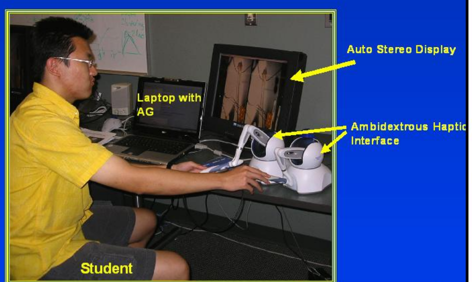
$$t_C = (F_{TC} (F_{DT}\, t_D))$$

Calibrated Video Client/Server Architecture for Medical Applications



Trainer Digitizing Station

Client Multi-Modal Interface



Usability Study

The assumption of this work is that a trainee surgeon can learn the complex hand-eye coordination necessary for becoming a good ophthalmic surgeon by feeling and seeing every move the expert surgeon makes, through a haptic, auditory, and visual playback interface. Is this true? What are the parameters of the Interface?

Experiment al Procedure

Twenty-five paid participants took part in this study, 3 women and 22 men, between the ages of 20 and 35.

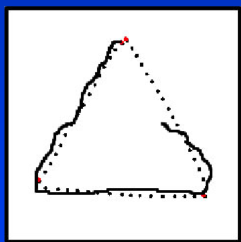
All of the participants reported a normal sense of touch and vision.

Two of them were left-handed, and the rest were all right-handed.

Experimental Design *(Short-Term Motor Skill Leaning)*

- T1: No-assistance training: No assistance of any kind was allowed in this mode. Learning occurred entirely through observation and physical repetition.
- T2: Visual training: Reference trajectories were visually displayed. Participants learned to reproduce the expert's movement by tracing the reference trajectories.
- T3: Visuo-haptic training: In addition to the visual guidance, participants' hand movements were physically guided by a PHANTOM device.

Visual Feedback



Haptic Feedback

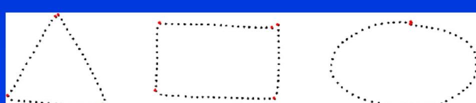
- Force feedback was triggered when the stylus end-effector deviated from the ideal trajectories as described above, and the end-effector was dragged back to the ideal path.
- The direction of the correction force was calculated by projecting the position of the end-effector onto a sub-trajectory.
- A sub-trajectory is a segment of the reference trajectory that was determined by feature points. The feature points were set where the reference path turned about an angle greater than 45 degrees.

Training Sequence

The order of training methods were counterbalanced

In total, 9(blocks) x 2(speeds) x 10(repetitions) x 12(participants) = 2160 user trajectories were collected for analysis.

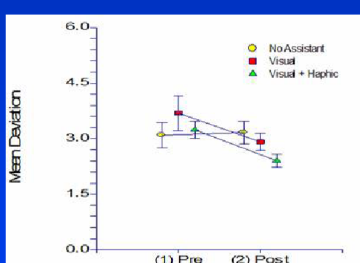
T1 T2 T3
T1 T3 T2
T2 T1 T3
T2 T3 T1
T3 T1 T2
T3 T2 T1



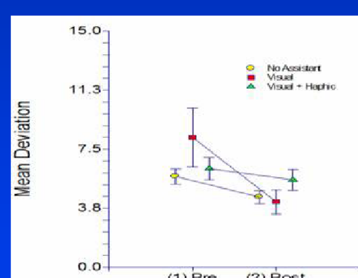
Training Results

		Pre-training	Post-training	Skill gain
Triangle	No Assistant	3.09	3.16	-0.07
	Visual + Haptic	3.24	2.4	0.84
	Visual	3.69	2.91	0.78
Rectangle	No Assistant	5.77	4.46	1.31
	Visual + Haptic	6.27	5.56	0.71
	Visual	8.25	4.16	4.09
Ellipse	No Assistant	2.06	1.9	0.16
	Visual + Haptic	2.04	1.78	0.26
	Visual	1.92	1.56	0.36

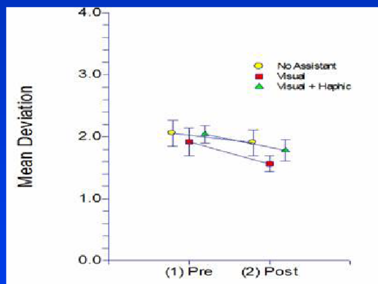
Results for the Triangle



Results for the Rectangle



Results for the Ellipse



Visual Feedback on Hand Movement

Our study shows that visual feedback dominates over haptic feedback because continuous haptic changes are hard to perceive by the human hand as it move. Better haptic device and new rendering algorithms are required.

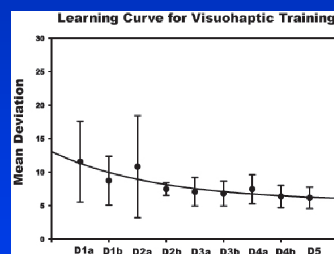
Experimental Design *(Long-Term Motor Skill Leaning)*

Training methods (Tn) and trajectory shape (Sn) pairs were counterbalanced.

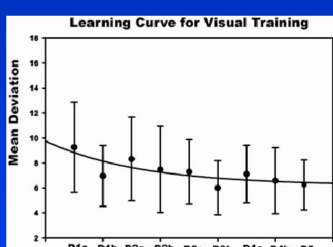
S1T1	S2T2
S2T2	S1T1
S1T2	S2T1
S2T1	S1T2

Where T1 refers to the visual training, T2 refers to the visuo-haptic training, S1 refers to the left trajectory

Long-term Learning (Visuo-Haptic)

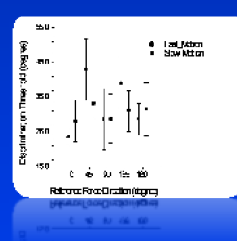


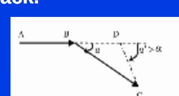
Long-term Learning (Visual)



Direction Threshold of Haptic Force

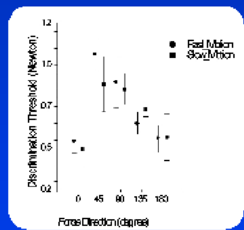
Our study reveals a mean difference threshold of force direction suggesting that if in the situations where the change of force direction is less than 32 degrees, additional visual cues should be provided for feedback.





Perception of Force Magnitude

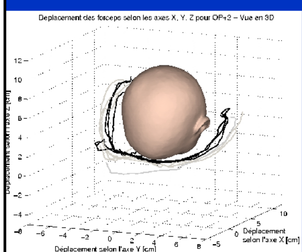
The relatively high force discrimination thresholds found in this study indicate that the perception of force magnitude is impaired when the hand is moving. The results also suggest that, in systems where haptic force magnitude needs to be changed frequently, the magnitude of haptic force change may need to be as high as 67% of the original force in order for people to detect a difference

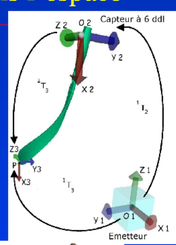


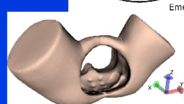
Birth Simulator (Virtual/Analog) (Collaboration with INSA of Lyon)

Le simulateur BirthSIM : un outil complet pour la formation sans risque en obstétrique

Visualisation du geste dans l'espace

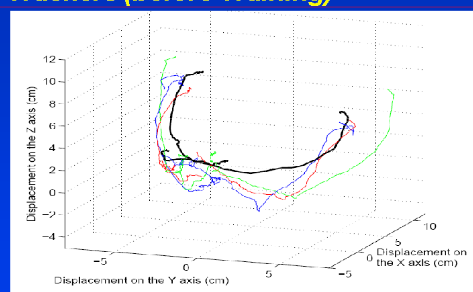




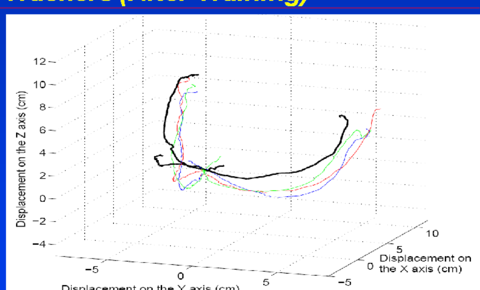


Le simulateur BirthSIM : un outil complet pour la formation sans risque en obstétrique

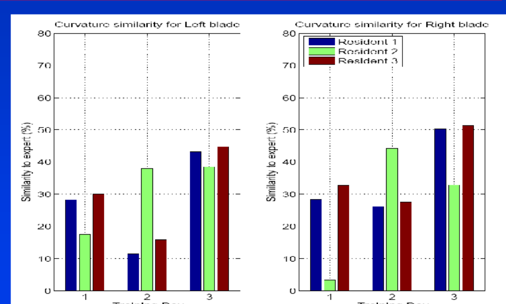
Trajectory Measurements Using 3D Trackers (before Training)



Trajectory Measurements Using 3D Trackers (After Training)



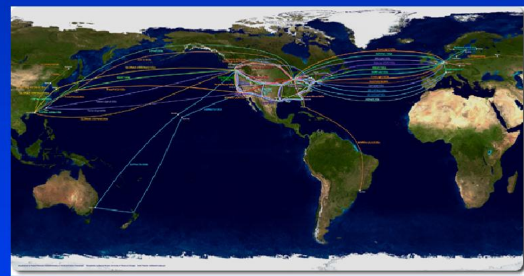
Comparison to Expert



Networking and Medical Training

- Next Generation Internet
  - Supported the applications described previously
  - Gigabit, QoS, multicast
- Scalable Information Infrastructure
  - Applications adapt to network limitations
- Grid computing and grid storage
- Optical Networks
  - Almost “Infinite” bandwidth
  - Ready to move to this level

Global Lambda



Future Medical Training Room at TRLabs Using HP HALO System

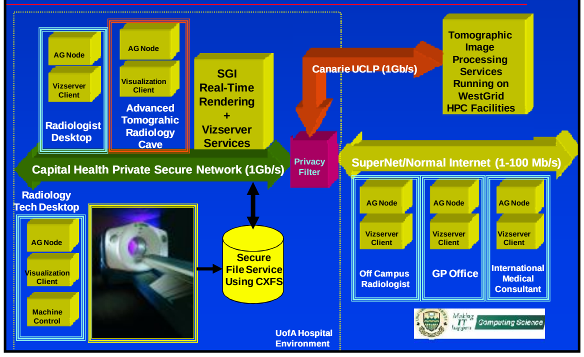
Public Unveiling of the MedPresence Conference Room

Barrow Neurological Institute

Phoenix, Arizona

January 23rd, 2006

MedViz: Collaborative Visualization/Instrumentation Control



MedViz: Advanced Collaborative Immersive Environments for Tomographic Visualization