VIRTUAL REALITY SIMULATION OF HIP SURGERY

By

Dr Phil Blyth

Supervised by Dr Iain Anderson, Associate Professor Susan Stott and Professor Peter Hunter

A thesis submitted in partial fulfilment of the requirements
for the degree of

Doctor of Philosophy

University of Auckland

2008

Bioengineering Institute,
University of Auckland,

14 November 2008

ABSTRACT

This thesis describes the design and application of a virtual reality simulator for orthopaedic surgery of the proximal femur. The aim of the research was to create a simulator with the following attributes; could be used within the current public hospital setting, reflected the perceived needs of the local orthopaedic community, provided surgically relevant feedback about aspects of technical ability to orthopaedic surgical trainees and the training committee, allowed practice of operative tasks which for reasons of radiation exposure could otherwise not occur, was validated, and could be developed further for other operations. The ultimate aim of the simulator is to allow trainees to practice aspects of surgical treatment such that their care of real patients is improved.

The novel aspect of this work has been the development of a simulator which allows the trainee to perform all the steps required for two surgical procedures; namely hip fracture fixation and pinning of slipped femoral capital epiphyses. The simulator runs on the computers found within the public hospital as it does not require expensive hardware such as haptic (force feedback) devices. Results from the simulator mimic real world measurements which are seldom available to trainees as feedback to enable them to practice their craft.

A survey of the New Zealand orthopaedic surgeons and advanced trainees showed this community was generally supportive of simulation, though only 4 respondents had previous experience with a surgical simulator. The task of practicing angulation/spatial orientation was thought most suitable for simulation, which is the task which the simulator specifically allows trainees to practice. More recently qualified surgeons were more likely to agree that simulation was an effective way to practice surgical procedures.

Validation of the simulator was tested in two experiments. The simulator was shown to have face validity; i.e. a realistic representation of the operating room. This result was obtained by surveying users who had completed a number of virtual operations. Construct validity was assessed by the simulator's ability to identify between groups of users with differing levels of real surgical experience. The simulator was able to discriminate medical students from orthopaedic trainees, despite the medical students' greater ability in computer-gaming. Advanced trainees generally performed better than basic trainees, though in the limited number of trainees available significance was not reached.

Finally the simulator was developed further to allow all advanced trainees within New Zealand to complete virtual pin placement of a slipped capital femoral epiphysis. This demonstrated the feasibility of using the simulator for assessment of trainees within their normal training weekend. It also revealed different operating styles, and showed how these differing styles do not correlate with the accuracy with which the final screw is placed.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

This work could not have been achieved without the tremendous support and advice of many people. It is my very great privilege to be surrounded by people with such great knowledge, as well as wisdom and experience.

Firstly I would like to thank my supervisors, Dr Iain Anderson, Assoc. Professor Sue Stott and Professor Peter Hunter. I really appreciate the time, effort and encouragement they have invested without which the project could not have been accomplished. I would also like to express my gratitude for believing that a medical doctor would be capable of producing something worthwhile with a computer, and not complaining when work seemed to overwhelm my research activities.

Within the Bioengineering Institute there have been a large number of people who indoctrinated me into the world of Linux, programming and networked computers. I would especially like to thank Steven Thrupp, Kumar Mithratne, and Justin Fernandez for their advice early in the project which enabled me to find direction (in multiple co-ordinate systems).

Within the medical community there have been several people whose help has been invaluable. These people include Mr Ian Civil, for insights into training issues and supporting my ongoing involvement within the hospital, Mr Ian Peters for his acumen in identifying the crux of a problem and Mr Bruce Twaddle and Mr Andy Campbell for their enthusiasm and support.

Within the Department of Anatomy with Radiology, Assoc. Professor Merv Merrilees for his erudite comments, Assoc. Professor Cynthia Jensen for excusing me from my work commitments to pursue this research, Mr Peter Cook for reminding me of the benefit of real and Mr Nick Duggan for his insights into computer gaming.

I would like to thank my family, my parents for their support of my decision to pursue an academic life, and Jessie and Elliot for showing that age is no barrier to successful virtual surgery. Lastly ki taku wahine Sue, for keeping our family together and happy as well as retrieving me when I got lost in virtual space.

GLOSSARY

Construct validity is the extent to which a test measures the trait that it purports to measure. One inference of construct validity is the extent to which a test discriminates between various levels of expertise.

Content validity is the extent to which the domain that is being measured is measured by the assessment tool—for example, while trying to assess technical skills we may actually be testing knowledge

Concurrent validity is the extent to which the results of the assessment tool correlate with the gold standard for that domain

Face validity is the extent to which the examination resembles real life situations.

Femoral Neck Fracture is more commonly called a hip fracture, and involves a break in the top of the thigh bone.

Haptics refers to the science of supplying touch (tactile) sensation to the user, such that the user can feel a virtual object. This utilises devices such as joysticks or datagloves.

Laparoscopic is commonly called keyhole surgery. This involves a fibre-optic scope and camera to allow surgery through small incisions.

Render is the term used to describe how a computer draws an object on the monitor.

Predictive validity is the ability of the test to predict future performance.

Inter-Rater or Inter-Observer Reliability. Used to assess the degree to which different raters/observers give consistent estimates of the same phenomenon.

Test-Retest Reliability. Used to assess the consistency of a measure from one time to another.

Internal Consistency Reliability. Used to assess the consistency of results across items within a test.

VRML stands for Virtual Reality Mark-up Language, similar to HTML but describes objects in 3 dimensions

From Plato's Phaedrus comes the story of Thamus. Thamus was a king in a great city in Upper Egypt. He was critiquing the inventions of a god called Theuth. These inventions included number, calculation, geometry and writing. Introducing his invention writing, Theuth announces, "Here is an accomplishment, my lord the King which will improve both the wisdom and memory of Egyptians. I have discovered a sure receipt for memory and wisdom"

Thamus replies, "Theuth, my paragon of inventors, the discoverer of an art is not the best judge of good or harm which will accrue to those practice it. SO it is in this; you, who are the father of writing, have out of fondness for your off-spring attributed to it quite the opposite of its real function. Those that acquire it will cease to exercise their memory and become forgetful; they will rely on writing to bring things to their remembrance by external signs instead of by their own internal resources. What you have discovered is a receipt for recollection, not for memory. And as for wisdom, your pupils will have the reputation for it without the reality: they will receive a quantity of information without proper instruction, and in consequence be thought very knowledgeable when they are for the most part quite ignorant. And because they are filled with the conceit of wisdom instead of real wisdom they will be a burden to society"

Phaedrus p96, by Plato

Chapter 1

1 INTRODUCTION

1. Introduction	2. Background	3. Attitudes towards Simulation	4. Development and Face Validity	5. Construct Validity	6. Slipped Capital Femoral Epiphysis	7. Future Work	8. Conclusion

Surgical training is showing signs of changing from an apprentice-style approach to a curriculum based method. Co-existent with a curriculum based method is the desire to provide a consistent experience for all trainees. Simulation is one method of providing this consistency. Virtual reality simulators have been a fascinating idea for some time, though simulators have only recently been available in surgery, and most commonly in general surgery.

This thesis describes the development of a virtual reality surgical simulator for orthopaedic surgery. Modules were developed for two types of hip operations. The aims of this research were as follows:

- To investigate the attitudes towards simulation within the orthopaedic surgical community.
- To design and develop a virtual reality simulator for some examples of hip surgery.
- To validate the simulator in a number of ways.
- To test the ability of the simulator to be used for assessment within orthopaedic training.

The attitudes of the orthopaedic surgical community were sought for a number of reasons. Firstly to identify whether the community felt there was a need for simulation, as this impacts on how much support there would be for incorporating simulators into training and continuing education. Secondly to identify the level of computer literacy within the community, this partially dictates the level of sophistication of the simulator interface. Finally questions identifying specific tasks or procedures were asked. This was in order to see how closely aligned the simulator which was concurrently being developed matched the perceived need.

As there was no virtual reality simulator for image guided orthopaedic operative procedures, part of the work towards this thesis involved designing and then programming a virtual reality simulator for hip surgery. The design constraints consisted of such things as making the simulator work using the computers found within the hospital system, thus enabling trainees to access the simulator at work, rather than travelling to a simulation centre. Other issues were incorporating the necessary decision-making steps within the operation, balancing the level of detail with the performance capabilities of the hardware and software systems and making allowances for trainees with different levels of computing experience.

Having designed and programmed the simulator, the next crucial factor involved validating the simulator. This validation should be done prior to using a simulator within training and/or selection of trainees. There are a number of different ways simulators can be validated. Face validation involves identifying how closely the simulation resembles the real procedure. A measure of construct validity is the ability of a simulator to discriminate between users with different levels of surgical experience. Transfer validity aims to determine how skills honed in a simulation environment improve performance in the clinical setting. This type of experiment is significantly more difficult to perform as there are a number of confounding factors such as obtaining an objective score for real world operative performance.

Major factors influencing the uptake of simulation technology include the ease with which the simulator can be incorporated into the training curriculum, and whether the simulator presents a challenge for the trainees. To this end the procedure of screw fixation of a slipped capital femoral epiphysis was simulated, and the simulator tested within one of the biannual training weekends, which are organised for all New Zealand orthopaedic trainees.

The originality of this work lies in its novel method of creating a surgical simulator for orthopaedic surgery, suitable for use on computers found in the current public health system. Rather than relying on high-tech hardware, such as haptic (force feedback) devices, the simulator uses a software based approach, which is both cross-platform as well as backwards compatible to early versions of computer operating systems. The focus of the simulator is on enabling trainees to practice angulations and the x-ray appearance of their guide-wires, without exposing patients to risks or the trainees to ionising radiation.

The work presented here represents the beginnings of how this simulator can be used for selection of trainees, training for new procedures, and assessment of how well trainees are progressing. The process of selecting trainees is becoming more topical as selection committees explore new methods to increase the objectivity with which trainees are chosen. Further improvement of patient care and legal defence of the selection criteria, are the main drivers for improving this objectivity. Training methods are becoming more topical as the public take a greater interest in the medical profession. Some no longer wish to be 'practiced upon' and others are challenging the concept of apprentice-style training. Assessment of performance may in time be more topical if colleges are challenged legally for failing to produce surgeons qualified to perform safely. These challenges may arise as limits on work-hours force a reduction in exposure of trainees to operative cases.

1.1 Publications Arising

The research presented in this thesis has resulted in five papers to date. These papers have either been published or submitted for publication to peer reviewed journals:

1. Blyth P, Anderson IA, Stott NS. Virtual reality simulators in orthopedic surgery: what do the surgeons think? J Surg Res 2006;131(1):133-9.

2. Blyth P, Stott NS, Anderson IA. A simulation-based training system for hip fracture fixation for use within the hospital environment. Injury 2007;38(10):1197-1203.

3. Blyth P, Stott NS, Anderson IA. Virtual Reality Assessment of Technical Skill using the Bon*e*doc DHS Simulator. Submitted to Injury.

4. Blyth P, Stott NS, Anderson IA. Virtual Cannulated Screw Fixation of Slipped Capital Femoral Epiphysis by Orthopaedic Surgery Trainees. Submitted to Journal of Bone and Joint Surgery.

5. Insull P, Kejriwal R, Segar A, Blyth P. Surgical inclination in senior medical students from the University of Auckland: results of the 2005 Senior Students Survey. N Z Med J 2006;119(1234):U1983.

1.2 Conference Presentations

Aspects of this work have been presented at a number of international conferences. These include:

1. Blyth P, Fernandez JW, Thrupp S, Anderson IA, Hunter PJ. Utilisation of VRML to Access a Cubic Finite Element Model of the Lower Limb to Teach Anatomy and Simulate Dynamic Hip Screw Placement. In: 4th Visible Human Conference; 2002 17-19 October 2002; Keystone, CO, USA; 2002. www.uchsc.edu/sm/chs/events/vh_conf/pdfs/039.pdf

2. Blyth P, Fernandez JW, Thrupp S, Anderson IA. A Method for Rapid Production of Patient Specific Femur Models. In: 51st Annual Scientific Meeting of New Zealand Orthopaedic Association; 2002 20-23 October 2002; Palmerston North, New Zealand; 2002. In: J Bone Joint Surg Br 2003;85-B(SUPP_III):p204.

3. Blyth P, Anderson IA, Stott S, Hunter PJ. Operating in a Virtual Theatre. At: 4th APEC Science Ministers Meeting (Innovation Showcase); 2004 9-11 March 2004; Christchurch, New Zealand; 2004.

4. Blyth P, Fernandez JW, Thrupp S, Anderson IA. A Method for Rapid Production of Patient Specific Femur Models for use in Virtual Surgery. In: 16th International Congress of the IFAA (International Federation of Anatomical Associations); 2004 22-27 August 2004; Kyoto, Japan: Blackwell Publishing; 2004. p. 342.

5. Blyth P. Use Of Virtual Reality For Teaching Difficult Anatomical Concepts. In: 2nd Annual Conference of the Australian and New Zealand Association of Clinical Anatomy; 2005 2-3 September 2005; Dunedin, New Zealand: In: Clinical Anatomy; 2005. p. 172.

6. Blyth P, Stott NS, Anderson I. Virtual Reality Simulators in Orthopaedic Surgery, What do the surgeons think? New Zealand Orthopaedic Association, Annual Scientific Meeting; 2005 2-5 October 2005; Christchurch, New Zealand; 2005. In: J Bone Joint Surg Br; 2006 May 1, 2006; 2006. p. 320.

7. Blyth P. Virtual Trauma. Injury 2005; 2005 4-5 August 2005; Auckland, New Zealand; 2005.

8. Blyth P, Stott NS, Anderson IA. Development and Face Validity of a VRML simulator for Hip Fracture Fixation. In: Medicine Meets Virtual Reality 15; 2007 6-9 February 2007; Long Beach, California; 2007.

1.3 Descriptions in the Media

The work has been reported in a number of different media, these include:

1. TV1 Network News. APEC meeting reports. TVNZ 10 March 2004.

2. Devereux M. Surgery simulator a risk-free trainer. The New Zealand Herald 2004 23 March 2004.

3. Dunning J. Simulator. Radio Rhema; April 2004.

4. Griggs K. Doctor Doctor A simple programme is reducing surgical training costs and risks. Unlimited 2004:17.

5. Meduna V. Virtual simulator for broken hips. In: Eureka. Auckland: Radio New Zealand; 2004.

6. Cyberworld. Taputapu Hou. Maori Television. June 2005.