Medical Visualisation Feasibility Study

FINAL REPORT

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Promoting further and higher education

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Ian Parkin	'A thorough understanding of anatomy is one of the crucial elements in ensuring safe, efficient medical and surgical practice. The Medical Visualisation Network is committed to producing digital models that will be viable, economical and highly efficient additions to teaching resources forboth undergraduate and postgraduate training'
Bertie Wood	'In the short time since the MVN came into existence, it has proved that a technological approach to anatomy teaching, which enables more rapid learning and superior comprehension. The introduction of movement to what traditionally has been a still subject allows huge educational advantage, as does the ability to build up body areas and layers. There are certain implications for medical undergraduate and postgraduate training, but also, and perhaps still greater, implications for the training and professional development of students and staff across a far wider spectrum including Nursing, Physiotherapy, Radiography, and the Paramedical Groupings. At present there is need for further financial underwritingn of a technology which may be sufficiently promising to add to Scotland's internationala standing'
David Rowley	'We have only touched the surface of the potential of this project and a continuation of the network will have genuine benefits in terms of patient safety; the way we teach and learn; and quite literally how we perceive the complexity of the human body and interact with it'
Bill McKerrow	'In my view the work ongoing in the DDS has demonstrated the huge potential of this technology in the range of areas outlined above and is an opportunity for a Scottish initiative to impact substantially on medical education and training on a worldwide basis'
Vivienne Blackhall	'The work of the medical visualisation network has the potential to revolutionize the way in which medical students learn anatomy. It brings anatomy to life and provides a straightforward approach to complex anatomical concepts. I wish it had been available to me during the undergraduate course!'

1. Introduction

This Feasibility Study was conducted for one year between January 2007 and January 2008. This report recounts the activities of the twelve months, describes the scope of the study through persons and organisations contacted, presents the case studies undertaken, on-going development work and concludes with a strategic overview of the area coupled to recommendations for the future.

The four sentences below set out the original context and high level aspirations for this study as presented to the Scottish Funding Council in May 2006. As such, they represent the aspirations against which the success of this Study should be measured.

> Traditionally, the only means medical practitioners have had to view real three-dimensional structures of the human body have been in the form of patients and cadavers. Now, however, advances in 3D visualisation technologies are making it possible to view and interact with such structures without the need or reliance on the use of real people or body parts.
>
> The ability to take vast quantities of existing two-dimensional sectional data, and render it into realistic interactive three-dimensional images has the potential to affect profound changes in medicine in terms of teaching, learning and cognition.
>
> The Digital Design Studio, together with the Royal College of Surgeons of Edinburgh, envisage the need for a sustainable, long-term network that will identify the key areas in future practice-based research in which 3D visualisation and interaction can support medical learning and teaching, surgical planning and rehearsal.
>
> Such a network of clinical practitioners, academics and visualisation experts with an interest in interactive real-time imaging, simulation and reusable learning objects, together with a natural constituency of medical schools and royal colleges, would provide Scotland with a profile in medical visualisation consistent with its existing international standing in medicine.

(Digital Design Studio, submission for funding, May 2006)

2. Executive Summary

The discussions that took place between the Digital Design Studio and the Royal College of Surgeons prior to submitting the application to the SFC for funding in May 2006, gave grounds for optimism that the time was right for an exploration into the benefits that 3D visualisation might confer to the teaching of anatomy, surgical rehearsal and training.

It is no exaggeration to say that the response to this Feasibility Study from the medical profession in general and to the formation of a dedicated Network has been overwhelming. There was an unreserved willingness and a spirit of cooperation on the part of all medical practitioners contacted to support the aims of the Study. The Study has resulted in the following achievements:

The formation of a truly inclusive network, The Scottish Medical Visualisation Network, numbering over 160 members, with representation from all of Scotland, 44 different organisations and 22 medical disciplines. This Network includes the five Medical Teaching Hospitals in Scotland, the NHS and the active participation of HMI of Anatomy for Scotland, Bertie Wood, the Royal College of Surgeons, Edinburgh and the Royal College of Physicians and Surgeons, Glasgow.

The formation of a Board of Management including leading academics, practitioners, surgeons and diagnostic experts, to agree policy and set strategy for the Network. This Board has now been renamed the Medical Visualisation Advisory Committee, and continues to guide the Network in enhancing its future research strategy and development.

The completion of five case studies in notoriously difficult fields each of which successfully demonstrated the rich potential of 3D visualisation to educate and inform where proper multi-disciplinary collaboration was developed between medical and visualisation experts. One of these, lung collapse, brought a new realisation that upturned conventional medical understanding and current teaching practice. The success of the case studies was instrumental in attracting additional funding from the Royal College of Surgeons, NHS Education Scotland, Ayr Hospital and Raigmore Hospital, Inverness.

Two, one-day Workshops the first of which introduced technology and techniques applicable to medical use and identified appropriate challenging case studies to be undertaken. The second workshop, much larger in scale, allowed the presentation of the outcomes of the five case studies. These presentations broke new ground in medical visualisation.

The publication of eight papers on the case studies given at international conferences.

Creation of a dedicated website as a vehicle for dissemination through public and members areas. The Scottish Medical Visualisation Network website has also been a means to further expand the Network and raise awareness internationally.

Recognition of significance by TV, radio and Press across the UK and internationally through articles and TV news presentations and WWW.

The Scottish medical student community, culturally versed in digital media, have approached the Medical Visualisation Advisory Committee to be part of the Network and gain further insight into their fields of study. A student member now sits on the Committee.

As important as the tangible achievements listed above, is the high level of expectation and aspiration created by the Network. This has fused as a single voice in support of results that clearly demonstrate a step change in the way that surgical procedures can be conducted and taught. The momentum thus generated demands continued support to realise the potential 3D visualisation offers in medical contexts and enhance Scotland's reputation internationally as a centre of excellence in medical teaching.

Since the end of the Feasibilty Study, funding has been secured from the Royal College of Surgeons, NES, Raigmore Hospital (Inverness), Ayr Hospital to conduct new case studies.

The work and vision of the Network and its expansion to include additional disciplines was presented to the Chief Medical Officer. The Medical Visualisation Advisory Committee presented the future strategy focusing on the development of the first definitive dataset for the 3D, interactive digital human for anatomical education, training and simulation.

3. Context

At the time the Feasibility Study was proposed, various reports and studies at national level revealed a gap in the knowledge base that pointed to the need for increased research activities in the field of medical visualisation for research, training and educational purposes. These reports and studies are summarised below together with key assumptions that formed the general context in which this study was conducted.

The review of Basic Medical Education in Scotland (Calman Report), June 2004, recognised that the funding of medical education research is problematic, and noted that medical education does not feature explicitly in the Funding Councils' Research Assessment Exercise. The review added that clinical skills training is of fundamental importance to medical students and supported the need to teach medical students specific clinical skills within a non-threatening environment, away from the pressures and anxieties of actual patient contact. The review emphasised the need for research in medical education and went on to recommend the creation of a Centre for Basic Medical Education that would encourage collaboration and new uses of technology.

Higher Education in Scotland: A Baseline Report, July 2004, analysed the data from the 2001 Research Assessment Exercise and reported that whilst there was a strong Scottish research base in generically biological or medical science based subject areas, there remained developmental opportunities in nursing and other studies and professions allied to medicine. The Scottish Higher Education Funding Council recognised the need for improving research in nursing and health by funding HealthQWest, which was launched in 2005. HealthQWest has identified its key priority themes as Decision Making, Function for Living and Gerontology. (None of these areas overlap with the key research areas identified in this study which focused more on the education of health professionals)

A Framework for Higher Education in Scotland: Higher Education Review Phase 2, (2003), recognised that the most exciting breakthroughs in research in the next decade were expected to be at the boundaries between disciplines, across the sciences, arts and humanities and that the funding system should encourage exploration at these boundaries. This study has operated across medical disciplines and through the extended field of visualisation that encompasses areas of computer science and human computer interaction as well as design, psychology and visual communication. It has explored new avenues of research that have the potential to contribute to Scotland's economic and social wellbeing.

Since the start of the Feasibility Study, an updated literature review (Appendix 12.3) has uncovered further background information that contributed to the project. Medical visualisation has been an active area of research worldwide over the last two decades. Only recently, however, has technology reached a level of maturity and cost/performance ratio that makes its deployment feasible on a large scale. In addition to providing scope to explore research in medical education and practice, this opens a window of opportunity for near-market research and product development that combines the underlying core technology with user-led know-how to deliver the solutions that today's market demands.

It is recognised that undergraduate anatomical training has been limited in recent years as the availability of cadavers for undergraduate training has significantly declined. Additionally, increasing student numbers and pressures from an expanding undergraduate curriculum has resulted in a reduction of students' exposure to cadaveric material and in total anatomical teaching time (Turney, 2007).

Supplementary teaching tools that involve book related material and PowerPoint presentations can also be perceived as unsatisfactory by medical students who experience significant difficulties perceiving three-dimensional information through two-dimensional means (i.e. diagrams and screen presentations). Although cadavers could be considered as a three-dimensional teaching tool, they offer very limited interactivity. Nor do they offer the repeatability that is required for the assimilation of knowledge regarding specific sections of the human body and complicated surgical techniques. Hence a student does not have the luxury to repeat specific dissections at his/her own pace and time in order to understand anatomical structures.

Additionally, many students are unable to mentally map and reconstruct 2D information derived from diagrams into a 3D context. Noticing these limitations, a number of studies have tried to replicate specific anatomy lectures through physical simulators. Although these may represent a first step to a more informative and stylised supplementary method of teaching anatomy they can be unrealistic and unsatisfactory for teaching more complicated structures.

Research has also suggested that medical and surgical trainees require anatomical resources that are convenient and adaptable to the desired educational content and techniques (Pandey et al., 2007; Ward et al., 2008). This observation was also supported by hospitals and medical schools across the UK highlighting the need for more approachable, simple and long-lasting training methods.

As a response to these requirements, some research studies have focused on the development of VR learning material. Initial results of comparative studies between traditional and structured VR training illustrated a significant shortening of the trainees' learning curves (Sang-Hack et al., 2006). Investigations involving similar medical visualisation techniques have also suggested that synthetic training environments are becoming an increasingly viable alternative to traditional cadaver anatomy training (Crossan et. al., 2002).

During their training period, medical students must develop a wide range of competencies including the acquisition of information and knowledge (e.g. anatomy), technical skills (e.g. laparascopic surgery), diagnostic skills (e.g. physiology) and 'practice' skills (e.g. collaborative working, and working with patients). Increasingly, these areas are taught in a complex environment with less tolerance for error. Computer based simulation offers the potential of an environment in which students can learn and practice skills without endangering patients and in which limited resources can be maximised.

Simulation offers significant advantages in learning and planning especially for rare, dangerous, and complicated procedures. With the integration of scan and other digital data, it offers the ability to plan surgical procedures using patient-specific information.

Computer graphics and machine vision laboratories both in the UK and abroad are already focusing efforts on this type of simulation as well as image generation for medical applications. Generally, they focus on the algorithmic issues for simulation, data extraction and representation, for example, the Computer Vision and Graphics Research Group at Glasgow University which develops methods for acquiring 3D surface topology for facial reconstruction.

Other research groups focus on particular aspects of clinical application, for example the collaboration between Medical Physics and the Institute for Materials and Processes at Edinburgh University to model blood flow though arteries; or the desktop system developed by Rutgers University, America for rehabilitating hand function in stroke patients.

Few of the resulting research outputs are integrated into clinical or teaching practice. This apparent disconnect arises partly from the early stages of development (from limitations of processing power and cost), and partly from the lack of an established route from patient-specific data to clinical application.

Against these issues, this Feasibility Study formed the view at the outset that it should focus on application and interaction, adapting advanced visualisation algorithms, toolsets and techniques where these would have direct impact on the needs of medical practitioners.

4. Original Aims & Objectives

An aim and a series of objectives were proposed to the Scottish Funding Council as part of the submission for funding. As they remained central to this Study, they are reiterated below.

Aim

The aim of the Feasibility Study is to bring together key individuals from medical schools, medical practice, Higher Education Institutes and other relevant organisations to identify future areas of research that address 3D digital visualisation and interaction and its impact in medical contexts. In particular, these contexts include risk reduction, real-time planning and surgical rehearsal, safer patient care, innovative undergraduate and postgraduate education, cost effectiveness and a better understanding of healthcare in general.

Objectives

This Feasibility Study sets out to:

- Establish a network of academics, clinicians, practitioners, medical and technical visualisation specialists, and basic scientists to identify the appropriate use of real-time 3D imaging and interaction to promote innovative and intuitive teaching and training methodologies.

- Identify areas where real-time 3D digital visualisation technologies can support education and training, including present and future clinical diagnosis and surgical rehearsal.

- Explore situations where 3D digital anatomical toolsets and models can be used by students and practitioners to repeatedly explore and diagnose, in order to augment and supplement cadaver-based practice

- Devise strategies where 3D visualisation can play a role in patient understanding and recovery, and the promotion of good health and well-being.

- Recommend on the strategic deployment of 3D visualisation with regard to the infrastructure model, clinical and pedagogical principles, and roadmap to practice. This will include forming appropriate partnerships and seeking funding streams to support research and commercial exploitation of resultant intellectual property.

These objectives will be achieved through the establishment of a steering group; a review of research within the field; the establishment and growth of a contact dataset; provision of two workshops; and identification of champions to represent specific areas of future research.

The Report of the findings of the Feasibility Study should include:

- A review of worldwide activities in medical visualisation and simulation in relation to professional education and clinical practice.

- Identification of the key areas of research in which future Scottish and UK initiatives could engage, including those areas where the health sector is active and where the introduction of state-of-the-art 3D visualisation promises the greatest immediate benefit.

- Recommendations on the best way to deliver subsequently identified needs. These will include the pedagogical, clinical, technological and future research development infrastructure required.

- A fully-costed plan for the next stage of this initiative.

5. Methodology

The Methodology through which the business of this Study was conducted was formulated by Professor Paul Anderson at the Digital Design Studio and Professor David Rowley of the Royal College of Surgeons. It was agreed that the formation of the Network was the first priority.

The Network
In creating the Network, it was agreed this should:

- Engage with a broad range of disciplines and working practices across the medical health sector.

- Investigate curriculum developments and challenges within medical teaching including major hurdles in the understanding of anatomical features, both in teaching and in diagnosis.

- Understand current imaging technologies within healthcare, such as CT imaging, XRays and MRI.

- Investigate gaps in knowledge and understanding within teaching, research and diagnosis.

- Gather together a broad range of specialised disciplines, especially where these disciplines do not normally interact and to identify territories and duplication.

- Ensure wide geographical representation from all parts of Scotland.

- Be 'neutral' in its outlook free of issue or political direction.

- Establish a series of live case studies to directly engage with anatomical and visualisation issues.

Board of Management
To coordinate the above, an Advisory Board was formed under the chairmanship of Professor Anderson. As reconstructed as the Medical Visualisation Advisory Committee, (May 2008) the Committee consists of :

Professor Paul Anderson, Digital Design Studio, Glasgow School of Art.
Professor David Rowley, Royal College of Surgeons.
Dr James Miller, Royal College of Physicians

and Surgeons of Glasgow.
Dr David Chanock, Consultant Radiologist, Ayr General Hospital.
Professor Philip Cachia, Postgraduate Dean, Ninewells Hospital, Dundee.
Mr Bill McKerrow, Consultant (Ear Nose & Throat), NHS Highland.
Professor Ian G Parkin, Applied Clinical Anatomy, University of Dundee.
Professor Bertie Wood, HM Inspector of Anatomy for Scotland.
Mr Gerry McGarry, Consultant (Ear, Nose and Throat), NHS Glasgow.
Dr Ben M Ward, Clinical Lecturer, University of Edinburgh.
Vivienne Blackhall, medical student, University of Glasgow.
Dr Vassilis Charissis, Researcher, Digital Design Studio, Glasgow School of Art.
Linda Brady, Network Coordinator, Digital Design Studio, Glasgow School of Art.

One of the first actions of the Committee was to name the network. It was agreed that the Scottish Medical Visualisation Network was appropriate.

The Network has grown to a current total of 160 members through invitation and latterly through a dedicated website. Once created, the Committee met on a monthly basis. This continues to be the case such is the significance of its momentum despite the end of the Study in January 2008.

Technical Issues
Technical issues were addressed through a series of targeted case studies which allowed themes associated with real-time 3D imaging and interaction to be explored in an anatomical context. This approach moved significantly away from the traditional world of 2D text and images to a fully interactive real-time 3D world, where data sets, anatomical structures and advanced imaging allowed interrogation and diagnosis to take place as viewed from both the practitioner and medical student standpoints.

To facilitate case studies, a world-wide review was conducted to locate the best possible 3D human data set. This was purchased from the Zygote Media Group. It was subsequently found to be inaccurate in part and missing in detail. Over the duration of the Study, this model has been systematically updated and improved and now probably exists as the most accurate and finely detailed model of its kind.

Workshops
In 2007 the Network met on two occasions through day-long workshops, the first on 29 May the second on 14 November. These workshops presented findings and practical demonstrations of 3D visualisation technology.

Location
Committee meetings, workshops and on-going research work were located at the Digital Design Studio. To inform the Network, a series of visits was also organised to various teaching hospitals and university departments throughout Scotland.

Dissemination
While the Committee used the vehicle of the Workshops to disseminate directly to practitioners, a website was formed to reach a wider audience. This website provides information for the public but also contains a members area where more detailed issues can be discussed.

The activities of the Network, in particular the Workshop of 14 November, attracted wide media attention in Scotland including a major news item on BBC Scotland as well as press and journal coverage.

6. Outcomes

This sections lists the tangible outcomes created by the Network including the Workshops and Case Studies.

6.1 Workshops

First Workshop – 29 May 2007

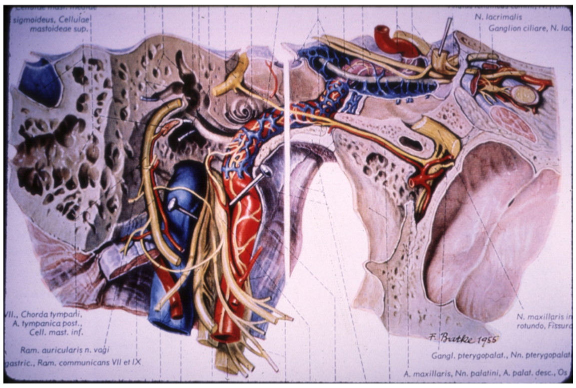
The aim of the first medical visualisation workshop was to establish a dialogue with medical disciplines throughout Scotland. This workshop was developed in partnership with the Royal College of Surgeons, Edinburgh, and had two main objectives. The first of these was to introduce current research and teaching practice involving anatomical structures and how this would benefit from the development of real-time 3D interactive imaging. The second was to develop a series of demonstrations to act as focal points for discussion and debate that would inform future development themes for exploration within the Feasibility Study.

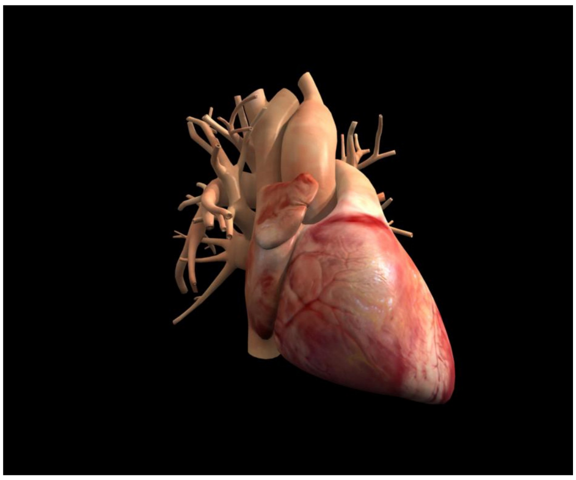
In addition to the two objectives above, the first workshop brought together a core group of Network members to assist in the identification and planning of future research themes in medical visualisation involving academics, medical practitioners, industrialists and visualisation experts. In forming this group, geographical representation covering all of Scotland was important as was ensuring that differing working practices and approaches were well represented. Consequently, delegates were invited from various regions ranging from the Highlands and Islands to the Borders as well as the Central Belt.

This workshop deliberately targeted a small number of delegates to allow a high level of interaction and involvement in the practical demonstrations and follow-on discussions. Although the target number for the workshop was small at 30+ delegates, a large range of disciplines were represented from medical teaching, anaesthesia, radiology, anatomy, surgery, urology and visualisation.

The group sought appropriate starting

Figure 1: 1st Workshop, 29 May 2007 - photographs and images from presentations (clockwise from top left): portion of cadaver; textbook illustration; presentation; discussion with workshop participants and 3D digital model of the heart.





points for case studies; identified challenges, determined an approaches to needs and learning outcomes. Speakers presented current practice in their fields and how use was made of advances in computer technology and visualisation techniques.

The workshop was also used as a technology showcase illustrating approaches taken in interactive 3D displays with content from other industries and disciplines. This was used to inform the workshop delegates of what was possible in other fields and what might be utilised within a medical context.

The group discussed the possibilities of 3D virtual reality and human-computer interfaces for resolving complex medical visualisation issues in the fields of surgical rehearsal, teaching anatomy, skills training, patient information and medical illustration.

Several themes were identified and prioritised as areas for multidisciplinary visualisation projects, five of which became case studies that were developed throughout the summer of 2007 and then presented in the second workshop.

The Workshop discussed means by which the Network could be established and decided that a multi-disciplinary Board should be formed.

See Appendix 12.4 for more information about this workshop.

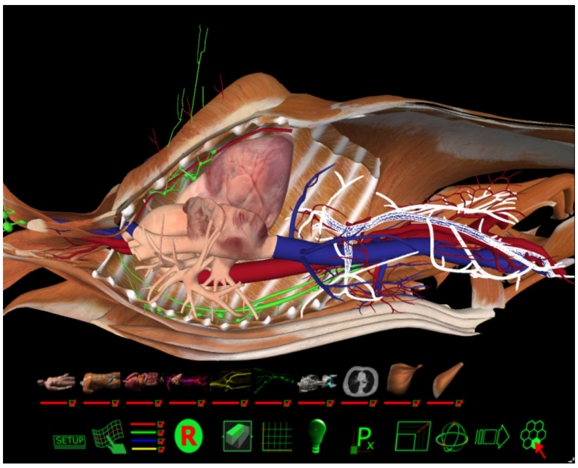
Between Workshops

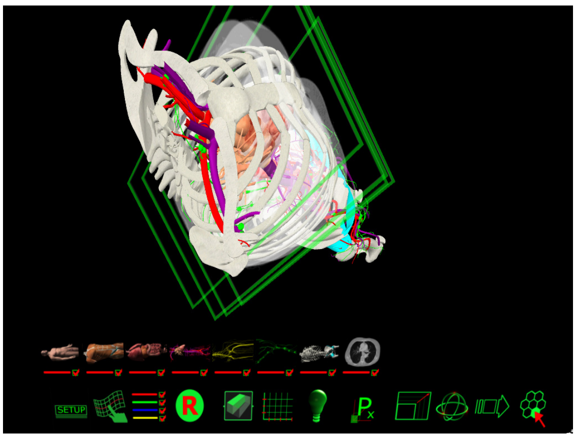
Following the first workshop, a Committee was established to guide and manage the 'Scottish Medical Visualisation Network'. The first meeting was held in June 2007, meeting on a monthly basis thereafter. Chaired by Professor Paul Anderson, the Board drew up a number of aims and objectives for the Network (distinct from the aims and objectives for the study as a whole) building on the discussions conducted at the first Workshop. It was also agreed that a website describing the work of the Network should be constructed.

Professor Philip Cachia from NES (National Health Education for Scotland) and ENT Consultant Mr Bill McKerrow of Raigmore Hospital, Inverness, joined the Board. The initial Committee of six has since expanded to its present compliment of 13.

The Network grew steadily to over one hundred by the end of the summer, 2007. As the Network expanded, case studies were identified

Figure 2: 2nd Workshop, 14 November 2007 - photographs and images from demonstrations (clockwise from top left): demonstration of the semi-immersive interaction tool for viewing 3D data; presentation to the audience; screenshot of the interaction tool with cross-section of the body; screenshot of the interaction tool, showing 2D layers of scan data superimposed on the skeleton and blood vessels.





and developed in the following areas:
• Breast Cancer
• Lung Collapse
• Foot and Ankle
• Lumbar Puncture
• Inguinal Canal
(see Section 6.2 Case Studies)

Second Workshop – 14 November 2007
The Second Workshop demonstrated the growth in numbers and excitement in general that the Study was generating. Seventy delegates attended from a total membership that now reached 120. Significantly, Richard Dimelow from the Scottish Government Health Quality and Safety, and HM Inspector of Anatomy, Professor Bertie Wood attended while the event was opened by the President of the Royal College of Surgeons of Edinburgh, Mr John Orr.

Professor Anderson described the Network's aims and objectives and introduced the Network's website. Professor Rowley, Director of Education at the Royal College of Surgeons of Edinburgh, emphasised the need for the Network and how it had a critical role to play in medical education.

Thereafter, the results of the case studies conducted by the Network were presented, including an interactive demonstration of a prototype haptic lumbar puncture simulator, introduced by Dr Jillian Hewitt-Gray of Ayr Hospital.

High quality 3D animations of lung collapse for teaching purposes were introduced by Dr David Chanock, also of Ayr Hospital, and a live demonstration of an ultrasound investigation of the foot and ankle was carried out during which the data produced was compared with virtual demonstrations and visualisations to improve the quality of teaching for radiologists.

After a networking lunch, attendees had the choice of visiting two of four demonstration-cum-discussion groups: the haptic lumbar puncture, the 3D heart, the virtual human body and the semi-immersive interaction tool for viewing 3D data.

For this workshop, medical students were introduced to the Study, first as user groups for the case studies, and then, as members of the Network itself. The students were enthusiastic about how 3D visualisation could help them with their studies and arranged to meet with Professor Anderson at a later date to find out how they could contribute to the Network as a group in their own right. Several radiologists requested certificates of attendance as part of their continuing personal development programme.

The event received substantial press for which Professor Bertie Wood provided the following quote for the Herald; 'What I saw today has unbelievable potential for medical education and surgical training'. See Appendix 12.5 for more information about this workshop.

Impact of the Workshops
While the second workshop was the last within the period of the Study which ended in January 2008, the Network continues to flourish. The workshops succeeded in providing a focus for discussion as well as a venue for networking by like-minded professionals from a wide range of disciplines. Membership was increased, sub-groups were formed and ideas for further research presented. There was a general consensus that, as a minimum, an annual event following the pattern of the workshops should be held.

At the time of writing, May 2008, membership of the Network has grown to 160. Medical students were identified as a sub-group of the Network. This group will be encouraged to grow and have their say within the Network as one of the main user groups. Plans are in place to establish a separate student area on the website. A student representative joined the Network Board in February 2008.

Scottish Medical Illustrators have organised an event in June 2008 to establish themselves as a stakeholder group and have invited the Committee to present the activities of the Network at the next Institute of Medical Illustrators' Conference in Durham in September 2008.

HM Inspector of Anatomy for Scotland, Professor Bertie Wood agreed to join the Network Board. He is an experienced administrator and medical educationalist, and his political awareness will assist the Committee in setting its strategic context. Dr James Miller, Chief Executive of the Royal College of Physicians and Surgeons of Glasgow has also joined.

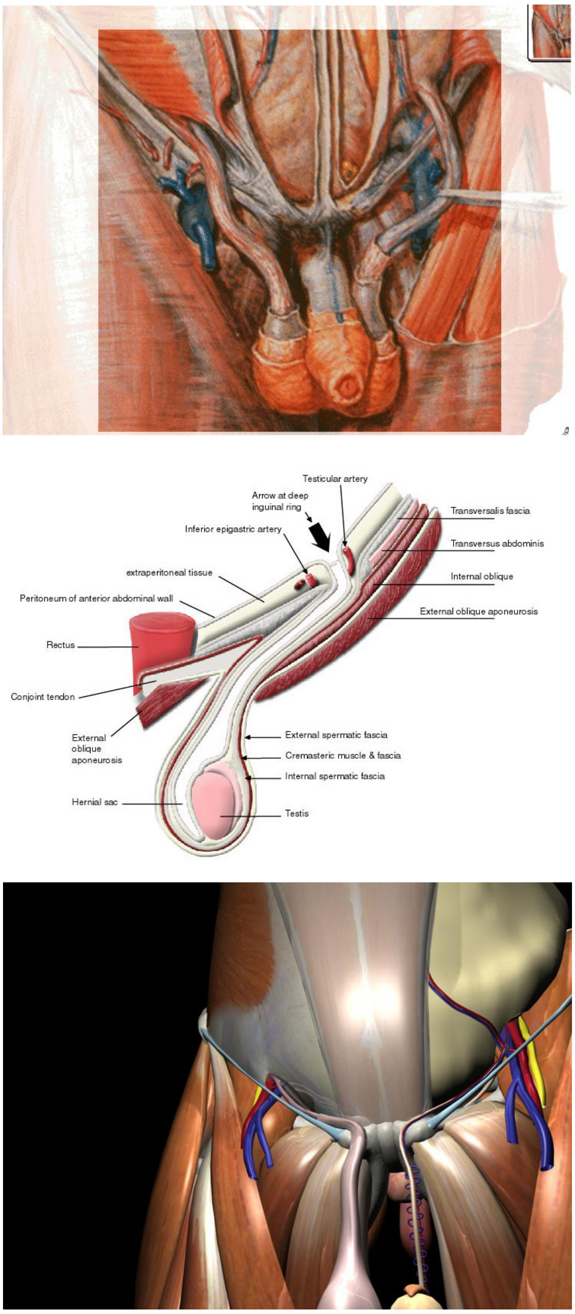
Further funded research projects are currently being focused on anatomy for chest drain simulation, the anal-rectal junction and the anatomy of the shoulder. These and other activities are outlined in Section 9.1.

Media awareness of the Network continued to grow resulting in articles in the press and internet, interviews on radio and a feature in BBC Scotland's News programme. These are detailed in Section 7.4.

6.2 Research Case Studies

The five case studies previously referred to used a variety of 3D models, animation, 3D visualisation, haptic interaction, and live scanning to examine and explore the feasibility of using such techniques in surgical rehearsal and procedure, radiological training and educational validation. A user-orientated approach was adopted using technical resources and expertise which the Network facilitated, principally, medical practitioners working with experts in 3D representation, programming and the human-computer interface.

Figure 3: Teaching the Inguinal Canal (from top down): simple 2D diagram; more detailed 2D illustration; image from the newly built 3D digital model.



The studies explore interface, content and application. They attempt to illuminate the breadth of applications within medical training at undergraduate and postgraduate levels and across disciplines. Most notably, all the case studies have been peer reviewed and published at major International and British conferences.

Each of the case studies is presented below, describing the motivation behind the study, the methods used (including empirical investigations where appropriate), and the potential impact of the project.

Case Study 1 - The Inguinal Canal

Many surgeons have suffered long hours of doubt about whether they will be surgeons or not because they lack an understanding of the underlying anatomy of the inguinal canal. The Network developed an interactive 3D model which demonstrates this complex anatomy in a format that demystifies the complexities, allowing interactive inspection of the canal as each layer of visual information is added.

In the male the inguinal canal is the route by which the vas deferens and testicular neurovascular bundle pass through the musculature of the anterior abdominal wall. Although functionally less significant in the female it is, in both sexes, an area of potential weakness. It is possible to develop three types of hernia in, or close to the inguinal region: direct inguinal; indirect inguinal; femoral.

It is essential that all doctors, and particularly surgeons, know and understand the anatomy of the region to facilitate accurate diagnosis, appropriate treatment and safe, effective surgical repair. It would be beneficial if patients also had a better understanding of the normal anatomy underlying their condition.

Current methods for learning about this region are unsatisfactory, and medical educators struggle to teach this complex area. It is extremely difficult to reveal the three-dimensional relationships of the walls of the canal, its openings and its contents by cadaveric dissection, leaving digital reconstruction as the only feasible method of promoting learning and understanding. Existing digital data on the inguinal region is inaccurate and incomplete.

This project took the most complete and refined 3D model available on the market, then manipulated and augmented it to produce a complete and accurate representation of the inguinal canal. The end result was a beautifully detailed 3D model of the inguinal canal area.

Each opening (the deep and superficial inguinal rings) was now visible and seen to be "protected" by two of the muscle layers. The muscles and their aponeuroses were clearly defined and two of them (internal oblique and transversus abdominis) could be seen arching over the canal to form its roof and then its posterior wall (conjoint tendon).

Nearby relations, fascial layers, and important surgical landmarks were also made clear. The complex anatomy was beautifully revealed to promote not only learning, but also full understanding of the region, as interaction with the model meant the area could be viewed from all angles. The result will be incredibly helpful to those learning about the inguinal canal for the first time, and also to those learning how to operate in the region.

The package must be further developed into one that is easily accessible to staff and to students (undergraduate, postgraduate, patient) in an interactive framework that may be used at levels and speeds appropriate to the individual. The addition of pathology would be extremely helpful, showing reconstructions of the different hernia types and their consequences.

Other anatomical regions are equally complex and difficult to reveal by dissection. Education in anatomy could be supported and enhanced by similar packages covering embryological development, the peritoneal cavity, laryngeal function, and movements of the eye, to name but a few.

Case Study 2 - Applied Surgical Anatomy in Malignant Breast Disease

This case study developed a 3D interactive surgical model of the human breast and axilla (armpit) with lymphatic drainage, with emphasis on the surgical landmarks for axillary clearance. This area has complex spatial anatomy, and understanding the anatomy is essential to understand the disease process and its management. Working in a collaborative fashion an extremely high fidelity rotational model was developed.

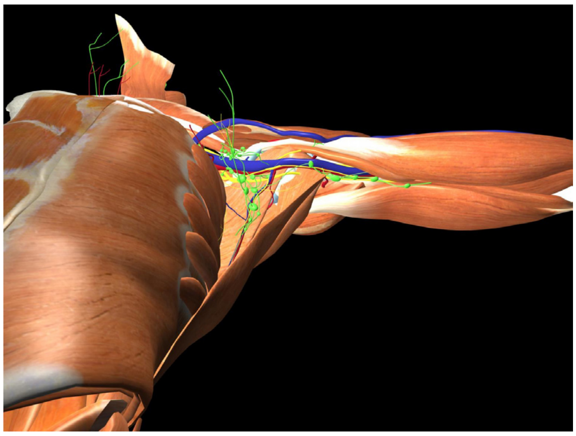
The model was presented in a semi-immersive display environment with an intuitive interface that would allow trainers and trainees to manipulate the true 3D model directly, reducing the steepness of the learning curve. Research studies focused on enhanced visualisation, haptic interaction and human computer interfaces.

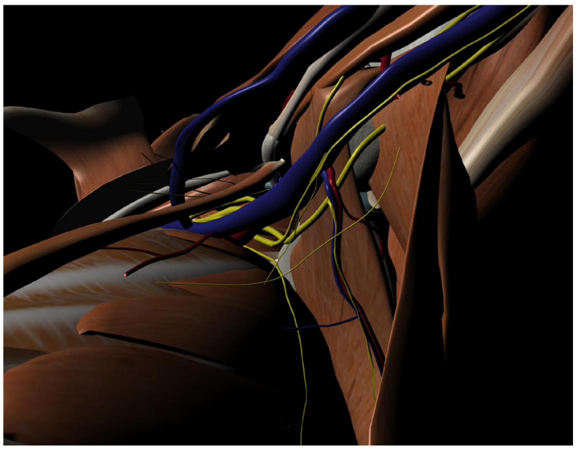
By blueprinting learning objectives directly from the Royal College of Surgeons Membership examination (MRCS) a curriculum was created to teach the subject using an activity based approach in which the semi-immersive 3D learning environment was used to augment small group tutorials.

A series of trials were conducted exploring experimental questions on attitudes, practical requirements and validation of methods, with very positive outcomes. Iterations of validation and development of the system improved learning outcomes by removing unnecessary barriers to learning.

The analysis of these trials with Foundation Year doctors from across Scotland offered an initial and encouraging view of the potential of this type of medical visualisation. The results from the trials offered a wealth of data that

Figure 4: Breast and Lymphatic Area top: photograph with area marked for surgery; 3D model showing axilla; 3D model of axilla (detail).





were further distilled and presented through a series of national and international publications. These trials are described below, illustrating the different aspects under investigation, and their routes of dissemination.

Case Study 2 Trial 1: An Enquiry into VR Interface Design for Medical Training
The problem of visualisation for medicine is multi-faceted, requiring a co-ordinated approach. A key component of any visualisation system is the development of an appropriate interface which allows the user to investigate the chosen content while avoiding a steep learning curve. Previous attempts in the use of VR for medical visualisation have struggled due to a lack of focus on the interface. By combining the educational approach with intuitive interfaces the user is freed to learn. As part of the initial case study, interface designs were developed specifically for medical training and tutorials.

This work was presented at IS&T/ SPIE international conference of Electronic Imaging in San Jose (Silicon Valley) California, USA. SPIE (International Society for Optical Engineering) is a world wide organization which supports an interdisciplinary approach and promotes advancements to the science and application of light. Its research includes the design and development of technologies in medical imaging and next-generation displays. The publication was presented by Dr. Vassilis Charissis and attracted significant interest from the delegates, particularly in respect of the interactivity attributes of the system and its application.

V. Charissis, B.M. Ward, M. Naef, D. Rowley, P. Anderson and L. Brady (2008), An Enquiry into VR Interface Design for Medical Training: VR Augmented Anatomy Tutorials for Breast Cancer, in Proceedings of the International Annual Symposium of SPIE, 27-31 January, San Jose, California, USA.

Case Study 2 Trial 2: An Evaluation of Prototype VR Medical Training Environment: Applied Surgical Anatomy Training for Malignant Breast Disease
Further to the initial trial an experimental approach was developed to validate the virtual model hypothesis and to learn more about the role of interaction, educational approaches and interfaces. The validation method built on the literature and aimed to look directly at learning outcomes; it also illuminated the trainee's perception of efficiency, utility and engagement.

A stakeholder group of Foundation Year doctors from across Scotland provided subjects for the study. Twelve subjects were randomized into two groups. They were pre-assessed and undertook a structured tutorial. One group was taught using existing resources (2D images, plastic models, text-books) and the other using the VR augmented system. External factors were controlled, and each group was debriefed using Multiple Choice Questionnaires (MCQs) and qualitative methods.

The study was designed to discover if the complex knowledge associated with spatial anatomy was improved by the VR system. The results were positive, demonstrating an improvement in learning outcomes related to spatial relationships. The approach was also found to improve engagement and encourage contextual learning, which is suggested to be a very important factor in promoting the use of knowledge in the clinical setting.

The findings were presented by Dr. Ben Ward at Medicine Meets Virtual Reality (MMVR) 16 in Long Beach California. The presentation created interest in the simulation community, mainly due to the integrative and streamlined approach demonstrated by the study. The paper was published in Studies in Health Technology and Informatics 132, IOS Press.

B.M., Ward, V., Charissis, D., Rowley, P., Anderson, & L. Brady, (2008), An Evaluation of Prototype VR Medical Training Environment: Applied Surgical Anatomy Training for Malignant Breast Disease, in Studies in Health Technology and Informatics, Volume 132, pp 550 – 555, Ios Press, (2008).

Case Study 2 Trial 3: Can Virtual Anatomy Augment Postgraduate Anatomy Teaching?
This study was trainee centred and explored issues in current specialist anatomy teaching such as real-world provision, suitability, engagement and learning outcomes. The focus was on Foundation Year Doctors as they represent the recent output of Scottish Medical Schools. They are also a good reflection of the new generation of learners (i.e. those that have never studied without the internet, never known a world without video gaming).

The initial trial was conducted at the Digital Design Studio in Glasgow and involved a volunteer group of Foundation Year Doctors from across Scotland. The group was evaluated for their prior exposure to anatomical teaching and surveyed to explore their experiences of currently available resources. The students were exposed to interactions with targeted

Virtual Anatomical models in a specifically designed semi-immersive 3D educational environment.

The results were interesting as the junior doctors had expressed concerns that the crowded undergraduate curriculum had left them unprepared for specialist training and that their personal attempts to learn were hampered by a complete lack of accessibility of appropriate resources. They were excited and engaged by the virtual learning materials, but were most impressed by the potential for the ready and immediate access that it offered. They also responded positively to the accurate, interactive and accessible nature of the 3D resources.

The results of this case study were released at the Edinburgh School of Surgery Day, reflecting dissemination back into the Scottish medical and academic community. The study was peer reviewed and presented by Mr. Ben Ward at the conference in November 2007.

B.M. Ward, V. Charissis, D. Rowley, and P. Anderson, (2008), Surgical Education: applied Virtual Anatomy: Can Virtual Reality Augment Postgraduate Anatomy Teaching? in Proceedings of the Edinburgh School of Surgery Day Conference, Edinburgh, UK.

Case Study 2 Trial 4: Surgical VR Training Environments: An inquiry into the application and validation of Volumetric 3D anatomy tutorials for operative surgical training.
Building on the previous developments it was decided to look at how the system could be used to maximize learning outcomes from operative exposure in surgical trainees. By using the system prior to a theatre session it was assumed that there would be an improvement in learning outcomes. This would allow a trainee to learn the relevant anatomy in context, with true spatial cues directly before proceeding to theatre.

The system was modified to maximize the intuitive interface so it could be immediately used in the clinical NHS setting. The principle was that a trainee could explore the surgical approach with a mentor prior to theatre, fail safely, see and discuss pitfalls and explore the anatomy immediately surrounding the surgical incision (in a way not previously available) free from constraint.

In addition, this pilot study looked at the possibility of simplifying the system to make it easier to use, small, portable and robust enough to be implemented practically. The work was presented by Dr. Ben Ward at SARS (Society of Academic and Research Surgery) Annual Conference in Birmingham and published in the SARS Yearbook Page 45 (2008).

B.M. Ward, V. Charissis, I. Young, D. Rowley, and O.J. Garden, (2008), An Inquiry into the applications and Validation of Volumetric 3D Anatomy, in Proceedings of the SARS International Conference, Birmingham, UK.

Case Study 3 - Lumbar Puncture
A doctor performing a lumbar puncture has very few visual aids available. Instead, he or she must rely on a thorough knowledge of the anatomy, experience and the feeling of touch to guide the needle. Today, the procedure is taught by watching an experienced doctor performing the operation and with the help of physical dummies simulating the various tissue layers.

However, current teaching methods have various shortcomings. The sense of touch cannot be acquired by watching the procedure. While physical dummies provide a good approximation, the materials simulating the tissue layers need to be replaced after each successful try; otherwise the next student could simply follow the existing canal. The materials, however, are costly. Given the shortcomings of the existing teaching methods, a computer simulation of the procedure was considered highly desirable.

This project developed a software prototype to simulate the lumbar puncture procedure. A clear spatial understanding of the anatomy it provides is extremely important as the procedure must later be performed with minimal visual cues. The software consists of a 3D anatomical dataset, a visualisation module, and a haptic (touch) simulation using the Phantom Desktop force feedback device.

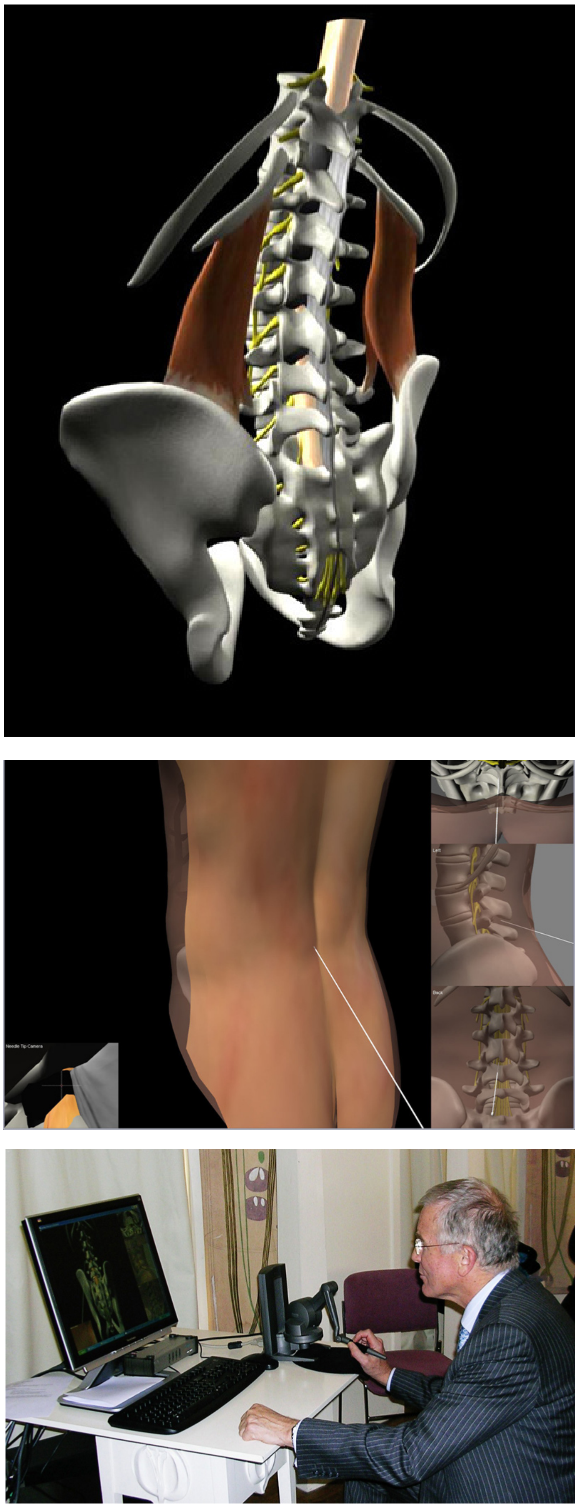
The dataset provides the base for both visual and haptic simulation, and covers the area of the back between pelvis and shoulders, including all the layers between the skin and the spinal canal; no internal organs are included.

The visualisation module includes three orthographic views (back, left and top) where only the bone and skin layers are enabled; these views are optimized to reduce visual clutter to effectively communicate the position of the needle relative to the spine. A large perspective view provides the most flexible visualisation; this view can be freely rotated and scaled using the mouse to look at various aspects of the local anatomy.

Individual tissue layers can be enabled, and a layer sequence is available to teach the order and spatial structure. A small view simulating a miniature camera attached to the tip of the needle provides additional spatial information while performing the procedure.

The user interacts with the application using the Phantom Desktop force feedback device.

Figure 5: Lumbar Puncture simulation (from top): the 3D model showing selected layers; screenshot of the visualisation tool showing different views and 'needle point' camera; the simulator in use by John Orr, President of The Royal College of Surgeons of Edinburgh, during the 2nd Scottish Medical Visualisation workshop.



The haptic simulation calculates the forces a surgeon would feel during the procedure depending on the needle position within the body. Additional interaction is provided using the keyboard to show or hide the individual layers and using the mouse to rotate the view.

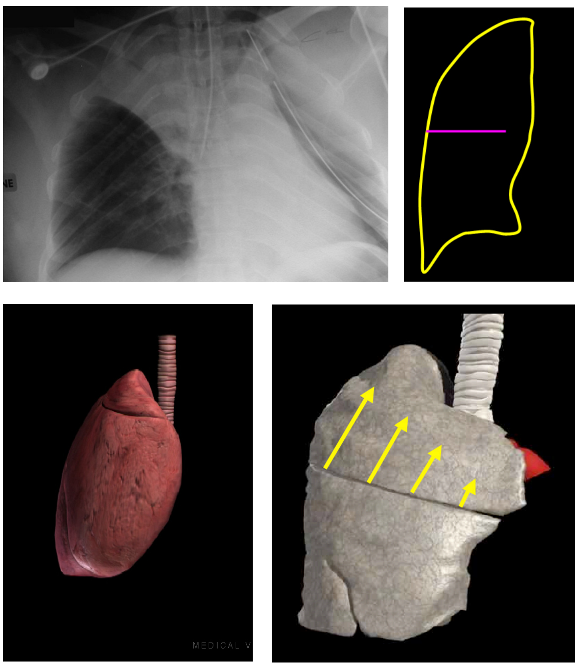
This project demonstrated the principle that a high-quality visualisation combined with haptic feedback can provide an exciting and powerful training tool for medical students. Future simulators developed from this prototype would improve the haptic simulation, the anatomy to provide a curved spine model, and a physical environment in which students performing a lumbar puncture can use their hands to feel the spine and provide a frame of reference to guide the needle relative to the patient.

The simulator developed as this case study requires relying on visual cues only, with an input device that is not visually related to the patient data in any way. Any future teaching tool must therefore integrate the force feedback device into a physical dummy to enable passive haptic feedback as a reference system.

Case Study 4 - Interpretation of Lung Collapse

Lungs collapse when a foreign body, infection or cancer obstructs one of the branches of the airway. Lung collapse is a notoriously difficult subject to teach as it requires a 4D understanding of anatomy i.e. a 3D spatial understanding of the region in a healthy state,

Figure 6: Lung Collapse (clockwise from top left): X-ray; simple 2D diagram; more detailed graphic illustration; screenshot from 3D animation of lung collapse.



and an understanding of the mechanisms of collapse in disease states. This case study looked specifically at research into the interpretation of CT/plain x-ray images of the chest in lung collapse. Interpreting 2D plain films of the chest demonstrating lobar collapses can be quite challenging; teaching their interpretation is even more difficult.

Using the methodology developed for the study on breast disease described above, the lungs and viscera of the chest were modelled under guidance from a consultant radiologist. This model was fully interactive in real-time, including the collapse of the lungs. By experimenting with computer simulations of volume loss, and utilising CT/MRI and plain film data alongside medical expertise, the model was developed to demonstrate in real time the process of each of the lobes collapsing. This was then linked to CT and plain film secondary images of collapse.

The system was designed to facilitate a 3D understanding of the process and integrate this understanding with the 2D imaging modalities. This application had the specific objective of integrating the teaching of specialist 3D anatomy with clinical procedure and image interpretation. Notably the system was designed to synchronously augment current clinical training or to be self-led and asynchronous. It was designed to convey the anatomy to a multi-disciplinary audience. The approach capitalised on current educational theory and enhances the current approaches by utilising advanced visualisation with an emphasis on practical and intuitive interfaces.

The model was presented at the second workshop and also as a lecture to 4th Year medical students at Glasgow University attracting encouraging feedback. The model and results will also be presented in Birmingham at the UK Radiological Congress 2008 by Mr. Ben Ward and Dr. David Chanock.

B.M. Ward, D. Chanock, V. Charissis, P. Anderson and L. Brady (2008), Interpreting Lung Collapse: A Randomised Controlled Study into the Impact of Three-Dimensional Animation, in Proceedings of the United Kingdom Radiological Congress (UKRC 2008), Birmingham, UK.

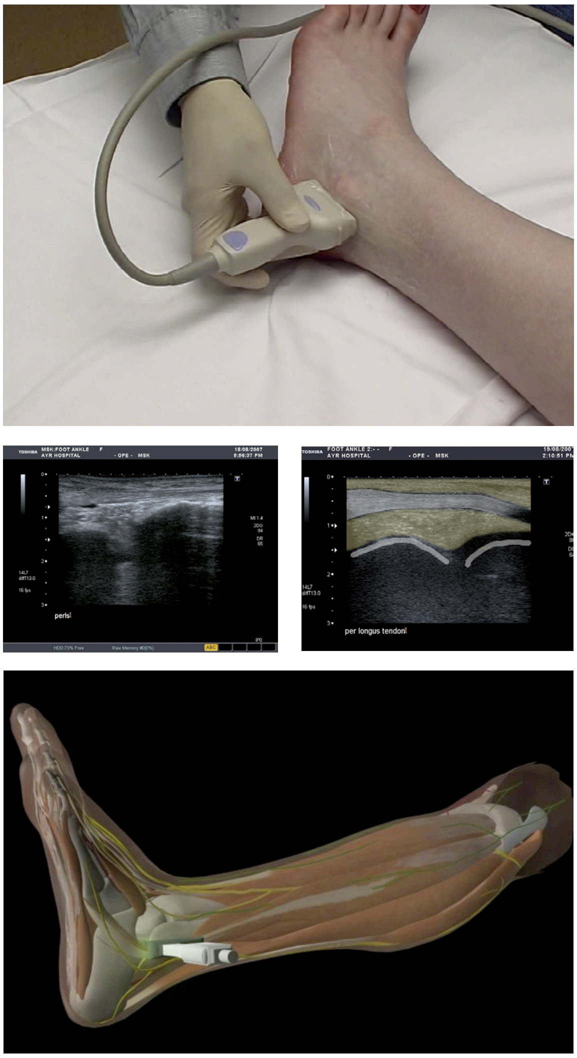
Case Study 5 - Musculoskeletal Ultrasound Training

This research project investigated methods of teaching practical imaging skills in tandem with applied anatomy, and was presented at the 2007 British Society of Rheumatology Foot and Ankle Course. Currently trainers are concerned that trainees are ill-equipped for specialist training and are forced to teach applied anatomy alongside practical skills in a clinical setting.

Ways in which users can improve their learning outcomes by the use of multiple sources of data in combination is currently of interest internationally. This study looked at the impact of interactive 3D models of the foot, ankle and lower leg when teaching musculoskeletal ultra-sound. Real time scanning with an actor and trainee was combined with real ultra sound images with a 4D animation of the structures over which the probe was passed. Hence students were able to collate complex procedural techniques alongside clear anatomical reference and interpretation of images.

In particular, a visualisation methodology was employed that allowed real time interlinking between a low latency rotational 3D anatomical model, visual descriptors of

Figure 7: Foot and Ankle (from top): scanning the ankle; ultrasound image; ultrasound scan with different tissues delimited; still from 3D animation of scan.



ultrasound technique (positioning, movement, field) and clinical ultrasound images. This teaching strategy linked the image directly to the anatomical structures and facilitated the learning of the procedure immediately in the way an expert uses the knowledge. This is the first example of this strand of research, and shows great potential for further development. As with other strands of this work the novel approaches have applications across medical practice and beyond.

This particular 3D model was developed as an explanatory tool, for complementing contemporary musculoskeletal ultrasound training. Initial trials suggested that the 3D representation of the procedure in conjunction to 2D data could be significantly useful as a training method. This is compounded when procedural techniques and specialist anatomy are effectively taught simultaneously. The model was presented at the second workshop in November 2007 and also as a lecture to 3rd Year medical students at Glasgow University with great success.

The next stage in this process is to validate the model using radiology trainees. This project is currently in progress in the West of Scotland deanery. Robust validation methods will be used to explore this interactive 4D approach to learning complex medical disease processes. The model and results will be presented in Birmingham at the UK Radiological Congress 2008, by Dr. David Chanock. The UKRC is a multidisciplinary Congress covering all aspects of diagnostic imaging and oncology, as well as radiology informatics and service delivery.

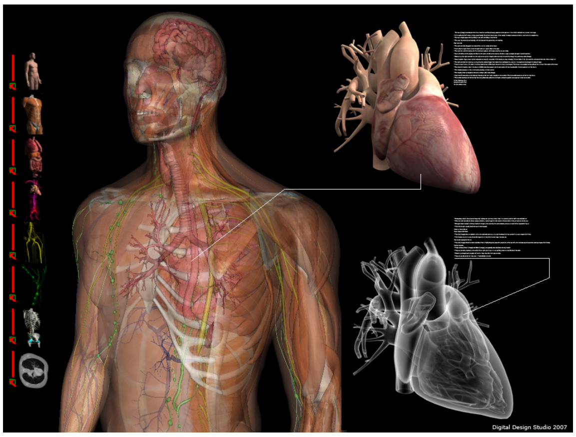
D. Chanock, V. Charissis, B.M. Ward, L. Brady, and P. Anderson (2008), Enhanced 3D Visualisation: Augmenting Musculoskeletal Ultrasound Training, in Proceedings of the United Kingdom Radiological Congress (UKRC 2008), Birmingham, UK.

Case Study Tools and Technologies

The technical implementation of the case studies was based upon a unified high-end visualisation technology platform that is used in various projects at the Digital Design Studio. This platform is a combination of commercially available development, content creation tools and custom software developed in-house by the DDS. Content creation refers to the process of creating the 3D models. All anatomical 3D data sets for the individual case studies were based on a commercially available male human 3D model purchased from Zygote. This data set is currently the most complete and refined 3D model available on the market, and was therefore chosen as the starting point. However, after consulting with various anatomists within the network, it was discovered that some of the data was inaccurate and a significant amount of detail was missing; this had to be added for the case studies.

The models were updated and built using Maya 8.0, a state-of-the-art 3D modelling tool with a particular strength on free-form surfacing. Unlike volumetric models as provided by CT or MRI scanning techniques or other methods (e.g. the Visible Human dataset), these 3D surface models are immediately suitable for real-time rendering and interaction and can easily be “stylized” to support teaching.

Figure 8: The 3D anatomical model (from top): female and male datasets; more detailed views of the model.

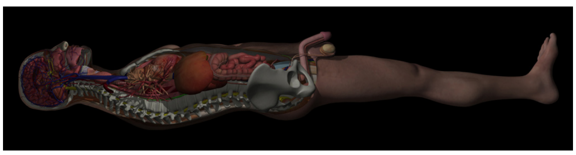


3D off-line rendering was also done in Maya in order to create the video materials required for the "Foot and Ankle" and the "Lung Collapse" case studies. Real-time rendering and interaction was implemented using custom software based on the Multigen-Paradigm VEGA Prime visualisation toolkit. VEGA Prime represents the current state of the art for visual simulation software. The "Breast Cancer" study also used the AutoEval software environment developed at DDS. The newly developed datasets and software were presented using a range of display and interaction environments. The "Lumbar Puncture" study used a desktop display system augmented with a high-precision force-feedback input device, the Phantom Desktop.

The "Breast Cancer" study used AutoEval, the Digital Design Studio's most advanced 3D interaction system comprising a Fakespace Workbench semi-immersive projection system with 3D tracking and tactile feedback on a data-glove for immersive interaction with the model.

Figure 9: The AutoEval 3D interaction system (from top); a surgical trainee examining the breast area; screenshot showing the interface.

Figure 10: View of high resolution 3D model available using the wide screen display.



All data sets can be displayed in real-time on other display systems at the DDS, including a high-resolution wide-screen solution which also provides an alternative configuration for passive-stereo viewing, (for the highest visual quality), and an active stereoscopic wall-display for increased spatial understanding and simple navigation using a robust game-pad.

All development work was conducted in close collaboration with medical professionals from the fields of radiology, surgery, and anatomical teaching to ensure precision and relevance of the applications and data sets.

7 Dissemination

Dissemination of the activities and ouputs of the Network has been wide and varied, including academic, professional and public audiences:

7.1 Website

The Scottish Medical Visualisation Network website www.medicalvisualisation.co.uk is the main vehicle for keeping Network members up to date with news, projects, events and publications. It was upgraded in February 2008 to include a members' area to disseminate news, published papers, research material and animations and presentations from Network events.

Although not envisaged at the start of the Study, the website is an invaluable tool for dissemination. Whilst it started as a simple information source about the Network in general, it is now security protected and its structure under development by the members. The cost of the website is being met by the DDS and the RCS.

7.2 Peer-reviewed Publications

The five case studies detailed in section 6.2 have resulted in eight publications, which are presented in Appendix 12.2.

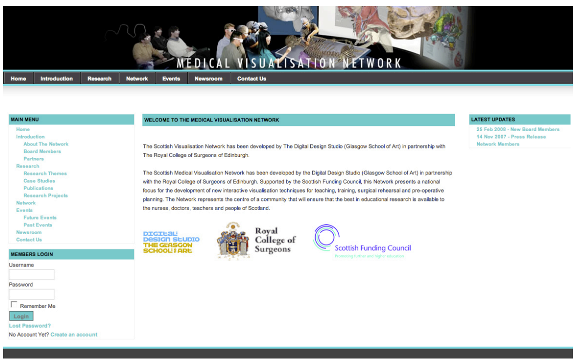
7.3 Press and Media

The establishment and work of the Network has attracted significant media attention, leading to printed articles in press and a range of interview and news features in both radio and television.

Articles in the Press

- "Virtual Patients for Surgery Practice". medGadget, Internet Journal of Emerging Medical Technologies, January 2, 2008.
- "Surgeons taught in a virtual world". (In feature, "Scotland Claims Two Medical Breakthroughs".) James Morgan, The Herald. Thursday 15 November 2007.
- "Now docs can walk 'inside' you". John McCann, Evening Times. Thursday 15 November 2007
- "Video Special: Now docs can walk 'inside' you" John McCann, Evening Times Online. Thursday 15 November 2007 (Includes video clip) www.eveningtimes.co.uk/news/display.var.1834562.0.0.php?act=login
- "A View from Tomorrow's World… Today" Metro. Tuesday 23 October 2007
- "Hi-tech lab gives a 3D view of our innermost secrets…" Ross McKinnon, Evening Times. Monday October 22 2007

Figure 11: Screenshot of home page, Scottish Medical Visualisation Network web site.



Television

- "Virtual bodies aid surgery skills" BBC Scotland News, Wednesday 2 January 2008 http://news.bbc.co.uk/1/hi/scotland/7167856

Radio

- Interview with Professor Paul Anderson (Director, Digital Design Studio) for Radio Scotland's Newsdrive programme, 15th November 2007.
- An interview with Professor David Rowley (Director of Education, Royal College of Surgeons of Edinburgh) for Radio Scotland's Good Morning Scotland programme; 15th November 2007
- Radio 5 Live. Live interview with Professor Paul Anderson. Broadcast Wednesday 2nd January 2008
- Good Morning Wales. Live interview with Professor Paul Anderson. Broadcast Wednesday 2nd January 2008

Other Websites

News items were reflected on the respective web-pages and attracted further international attention.

http://news.bbc.co.uk/1/hi/scotland/7167856
http://www.newspeida.eu/news/11494/virtual+bodies+aid+surgery+skills
http://24hnews.net/Health/Virtual-bodies-aid-surgery-skills.html
http://www.iran-daily.com/1386/3034/html/science.htm
http://medgadget.com/archives/surgery
http://hospitalnewswatch.com/aggregator?page=22

8 Financial Statement

8.1 Budget granted by SFC
The sum of £97,105 was originally requested from the SFC. However a 10% reduction was requested which resulted in the sum of £89,722 being granted for the one year Feasibility Study based on the following costs (See Table 1):

The costs included a full-time researcher, the services of the Director of the DDS, travel costs and the expenditure required to run two workshops:

- Researcher: the duties of this position included administrative support to the Network and Committee (including arranging the workshops) in addition to research activities.
- Travel costs: these included a budget for the PI and Researcher to travel to university and NHS research centres to conduct interviews with researchers and practitioners, and to survey ongoing research activity.
- Workshop costs: these covered room hire, catering, travel and subsistence costs for attendees, the Committee and Researcher, as well as the preparation of materials for dissemination. The costs were estimated on the basis of 30 persons attending each workshop.

8.2. Actual Income and Expenditure
During the period of the Study, the initial grant from the SFC was supplemented by cash contributions from the Royal College of Surgeons and Ayr Hospital to give a total income of £94,897 (See Table 3). Total expenditure was £100,504 representing an overspend of £5,645 or 5.95% to the period end (See Table 2).

Directly Incurred Costs
Salary costs for the Researcher at £33,363 were slightly less than the anticipated £36,601. Travel costs were also less than anticipated. The Committee agreed to meet on a monthly basis at the DDS and covered their own travel costs. However, other direct costs were much higher than anticipated.

It became clear after the first workshop that additional money would be required to develop the case studies. In particular, a 3D model of the human body was purchased along with appropriate software and licences. The RCS and Ayr Hospital contributed a total of £5,175 towards these additional costs.

Although the case studies were largely carried out by the DDS and members of the Committee, additional modelling expertise was bought in at a cost of £1,576 to allow completion of a specific case study before the date of the second workshop.

The success of the Network meant that the original estimate of 30 delegates for the second workshop was underestimated as numbers eventually rose to 70. Together with venue hire, printing and other sundry costs, expenses for the second workshop amounted to £6,640.

Directly Allocated and Indirect Costs
While costs were allocated as originally intended, after the first workshop in May 2007,

TABLE 1. Table of estimated costs (based on Full Economic Costing)

Item	Description	Cost
Directly Incurred Costs		
Researcher	Direct cost of a researcher for 12 months based on current salary bands. Includes superannuation and NI, but excludes inflation.	£36,601
Travel	Budget for travel to other universities and NHS research centres, and travel associated with Management Group activities.	£3,000
Other	Cost of organising and hosting 2 workshops. Includes VAT.	£3,000
Directly Allocated Costs		
Project Supervisor	Services of Professor Paul Anderson (average of 4 hrs/wk) to direct the Feasibility Study.	£8,458
Indirect costs		
Estates	Rates set by Institution; calculated on FTE	£7,985
Indirect	Rates set by Institution; calculated on FTE	£30,678
	Total Cost	£89,722

Professor Anderson substantially increased the amount of his time spent on the project.

Additional Costs
As the Network proved to be a success, it was decided to establish a website where members could be informed of the latest information, news and events. The cost for this was not anticipated in the original budget. This is being met by the DDS and the RCS. The amount spent so far (May 2008) on domain names, web set-up and staff training has been £2,623.

The case studies were presented at two international conferences in the USA. The cost of sending two researchers to these conferences was £3000. The total estimated additional costs therefore amounts to £5,623.

Post Feasibility Study Income
The Feasibility Study was completed in January 2008. However, the DDS, the RCS and the members of the Network are committed to the continuation and growth of the Network. To ensure continuity of personnel and activities, the RCS invested £30,000 immediately after the SFC funding ceased. In addition, funding has been secured from various other sources to carry out specific research projects for example NES and Raigmore Hospital, Inverness.

At time of writing, this income is estimated at £78,908. Full details of post-feasibility activities can be found in the Section 9.1.

TABLE 2. Table of expenditure for the Study

Item	Description	Cost
Directly Incurred Costs		
Researcher	Direct cost of a researcher for 12 months including superannuation and NI.	£33,363
Travel	Budget for travel to other universities and NHS research centres, and travel associated with Management Group activities.	£965
Other	Tools, technologies and software for case studies, 2 workshops.	£19,093
Directly Allocated Costs		
Project Supervisor	Services of Professor Paul Anderson (average of 4 hrs/wk) to direct the Feasibility Study.	£8,458
Indirect costs		
Estates	Rates set by Institution; calculated on FTE	£7,985
Indirect	Rates set by Institution; calculated on FTE	£30,678
	Total Expenditure	£100,542

TABLE 3. Table of income over the Study period
Expenditure

Income	
SFC Grant	£89,722
Other (RCSed, Ayr Hospital)	£5,175
Total Income	£94,897
Expenditure	£100,542
Overspend	£5,645

9 Continuing Research Activities

Although the period of the Feasibility Study is now complete, such is the momentum of the Network that activity remains at a high level. Funding has been secured for a number of projects which are underway, a series of funding applications is in preparation, and the first PhD studentship arising from the Network is due to start in the next academic year. The Network is also continuing to develop contacts with medical, academic and industrial organisations through one-to-one meetings, events and conferences. These research partners are listed in Appendix 12.6.

9.1 Current and Agreed Future Projects

Support for ongoing network activity

The Royal College of Surgeons of Edinburgh contributed £30,000 to support the continuing activity of the Network, particularly providing continuity of personnel, and the development of the web site.

The Anal-rectal Junction

Visualisation of the anal-rectal junction was funded by NES (NHS Education Scotland) at a cost of £7,508. There is a need for accurate 3D imaging of the anal-rectal junction, a very complex structure which is difficult to visualise and teach.

This project is creating an initial, detailed, 3D model comprising anatomy and structures of the anal-rectal junction which will allow students and practitioners to understand and comprehend the complex layers and structures of this region.

The foundation work associated in developing this model has huge potential to be used as an educational tool for visualising and enhancing the understanding of this complex structure. The outcomes resulting from this project will subsequently be used to develop a simulator for laparoscopic colorectal surgery, with the potential to put Scotland at the forefront of colorectal laparoscopic surgical training.

Similarly, this work will give surgeons better confidence in pre-operative planning of laparoscopic colorectal surgery. Project conclusions will form the basis of a larger future research programme focusing on building a haptic real-time simulator for laparoscopic colorectal surgery. The Skills Centres in Aberdeen and Dundee, together with the Scottish Clinical Simulation Centre in Stirling, have expressed an interest in this type of visualisation work.

Chest Drain Simulator

The Committee identified the need for accurate 3D imaging for the insertion of chest drains, particularly with reference to pneumo-thorax and pleural effusion. This procedure, which can have critical consequences if performed wrongly, is normally taught to Foundation Year 2 students using pig carcasses.

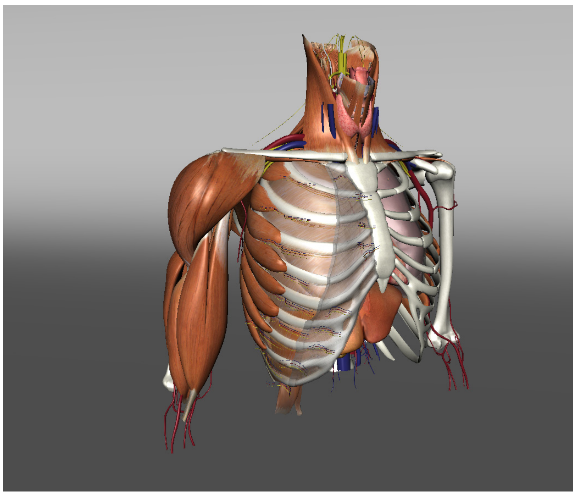
There is a requirement for a simulator that would allow students to practice the technique of inserting chest drains using the correct anatomy, while retaining the physical feedback received when inserting drains through skin and muscle. This haptic simulator will be accompanied by an animation demonstrating how the procedure should be carried out.

A three-week project valued at £6,400 has been funded by NES representing the first stage of the development of such a chest drain simulator, comprising the development of a detailed 3D digital model of the anatomy of the chest, lungs and thorax, and the animation demonstrating the correct procedure. It brings together visualisation and modelling experts with the very necessary medical diagnostic input of a leading clinician and anatomist.

This work has the potential to permit safer, less traumatic surgical procedures because of its ability in rehearsal using the correct anatomy. Further development of a new simulator will allow high degrees of repeatability in a training scenario without the need for consumables associated with current practise.

This simulator would allow students with no experience of the procedure to rehearse the insertion of chest drains with a greater understanding of the 3D human anatomy (not animal) and the penetration of underlying structures. This approach satisfies the need to produce repeatable training experiences for multiple student groups.

Figure 12: Chest Drain Simulator: 3D Anatomy.



3D Modelling of Shoulder Anatomy

Anatomy of the human shoulder is complex and multi-layered, making it a challenging area for traditional anatomical teaching and surgical training. This preliminary pilot study, funded by the Centre for Health Science in Inverness and valued at £10,000, is creating an anatomically accurate digital dataset of healthy shoulder anatomy, incorporating the multiple structural levels from bone, cartilage and ligament etc., out to the surface covering of skin. The dataset can then be manipulated, explored and tested using 3D VR equipment by a variety of target users, including students, physiotherapists, doctors, surgeons and radiologists.

Although relatively crude, '2.5D' illustrative resources are currently available, this project is an entirely new work, unprecedented in terms of its accuracy and true 3D VR capability. The shoulder region is a particularly appropriate study as the Inverness Group has collective expertise in the fields of shoulder physiotherapy, surgery and diagnostic imaging (CT, MRI and Ultrasonography).

After successful development of a tangible and demonstrable pilot system, there will be considerable scope to develop the model further, incorporating a range of realistic disease and injury characteristics commonly found in the shoulder. Arthritis, rotator cuff disease, fractures and dislocations are pathological conditions eminently suitable for 3D VR modelling.

Practical applications could include teaching of medical students and theatre personnel, training of physiotherapists and GPs in injection techniques, rehearsal of shoulder operations, development of joint prostheses and fracture fixation devices.

Documentary Film on Mediaeval Medicine

This project, funded by Wild Dream Productions and valued at £5,000, is for a series being made for the History Channel about mediaeval medicine. In 1403, Prince Hal, later Henry V, received a grievous injury when an arrow penetrated and became embedded in his head below the eye. The programme makers regard the DDS 3D facility as the most appropriate in the UK with which to study this celebrated example of early surgery where the surgeon/blacksmith was able to remove the arrow. Part of the programme was filmed at the DDS with a neurosurgeon describing the procedure using 3D visualisation. (See Figure 13)

Designing Out Infection

Funded by Birmingham NHS, in partnership with MidTech Innovations, this project focuses on building and developing a strategic design methodology that addresses infection control and reduction.

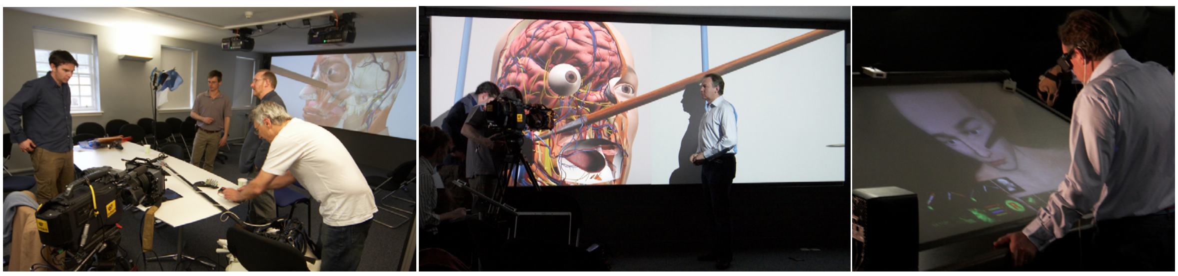
Phase 1 (£25,000), was a twelve-month study completed in December 2007. It focused on the identification of suitable areas for intervention. It produced preliminary proposals to support a strategy for 'Designing Out Infection', and in the process, informed and educated various parties as to how product opportunities are assessed and developed. Investigations were conducted through a literature review, interviews and hospital visits.

Phase 2 (£20,000) started in April 2008 and builds on the success of Phase 1 and focuses on building rapid prototypes of mobile stands and equipment as they are associated with the spread of contaminants and infection.

9.2 Ultrasound Anatomy and Techniques for Regional Anaesthesia

A collaboration between GE Healthcare, the Digital Design Studio and The Scottish Medical Visualisation Network has been proposed to develop a new interactive teaching package to demonstrate ultrasound anatomy and techniques for regional anaesthesia. This new, interactive training package will employ interactive 3D tools and models that are anatomically groundbreaking in their clarity

Figure 13: Documentary on Mediaeval Medicine - images from filming (from left): filming at the Digital Design Studio; using the wide screen display to illustrate the problem; explaining the procedure using the AutoEval 3D interaction system.



and interactivity. The proposal, valued at £180-200K has been accepted at both UK and EU level, and is awaiting approval from the GE Healthcare USA.

Arthritis Research Campaign (ARC)
The ARC has moved toward the commissioning of educational projects rather than inviting them through open call. Negotiations are beginning with ARC for commissioned research that fits with their new educational strategy (published in January 2008). Mike Patnick from ARC visited the DDS in February 2008 to hear about the activities of the Network and the potential for new research development. A further meeting with ARC's London office is being arranged.

PhD Studentship
The first Network PhD is expected to start during 2008. This studentship, funded by Ayr Hospital, will be part time, and based in the DDS where Professor Paul Anderson will be the lead supervisor with a second supervisor appointed from Glasgow University Medical School.

9.3 Contacts in Development
The Network is continuing to develop contacts with individuals and organisations through meetings and events.

Scottish Medical Illustrators Workshop
In June 2008 the Scottish members of the Institute of Medical Illustrators (IMI) held a workshop at the Digital Design Studio (DDS) for an introduction to the Network and its research activities. Professor Anderson reprised the activities of the Network and discussed the portential for future intercation with IMI in new research initiatives.

The IMI is the Illustrators' professional institute of choice and the leading body of its kind in Europe. Recognised by the Department of Health, the IMI exists to promote the role of the Medical Illustrator as a professional member of a multi-skilled team who offer a range of core clinical illustrative and communication services as part of the healthcare team for the benefit of patients and clients.

Contacts
The Network continues to develop strategic contacts for future development from a range of academic, medical and industrial organisations including the Scottish Government. These include :

- The Heads of the Scottish Clinical Skills Network based in Aberdeen, Stirling and Dundee.
- MEDiVision. This Australian company, which has links to RCS, manufactures medical simulators. They are interested in our techniques and a potential partnership.
- The Committee has made direct contact with the Chief Medical Officer for Scotland and presented the future strategy for the Medical Visualisation Network. As a result of this meeting, the CMO has recommended that the Deputy First Minister be appraised of the activities of the Network and its potential contribution to medical education and patient safety in Scotland.

10 New Strategies

The future vision for the Network is to develop funding streams that will support a dedicated full-time research and development team over the next four years based at the new DDS facility based at Pacific Quay in Glasgow. This facility is due to come on line in March 2009. Lab 1, in this facility will be one of the largest 3D interactive labs in Europe and will be focused on developing the first definitive dataset for the 3D interactive digital human. This ambitious research and development programme was recently presented to the CMO. The creation of this dataset, will allow innovative approaches to anatomical teaching and research for the five medical schools across Scotland. Key areas for development will include patient safety, promoting safe practice and reducing risk.

It is intended that the multi-disciplinary nature of the Network will expand to include paediatricians, physiotherapists, paramedics, nurses and dentists. The creation of the definitive anatomical data set for both male and female will allow significant research development to take place across a range of disciplines.

As a result of the activities conducted within the Feasibility Study, the Committee identified a set of future aims for the Network, together with four thematic areas of applicaton. These areas have been selected where 3D visualisation and interaction are likely to have the most immediate impact. These aims are:

10.1 Future Aims and Themes

- To create the first definitive data set for the 3D digital interactive human (male and female)
- To establish an interdisciplinary network for new approaches to medical teaching and clinical diagnosis.
- To create innovative techniques, tools and methodologies to support anatomical teaching and training.
- To develop 3D visualisation and interaction in support of surgical rehearsal and pre-operative planning.
- To promote understanding of lifestyle behaviours, disease processes and healthcare issues in a patient centred context and to the wider general public through visualisation.
- To enhance post-care management through visualisation to positively impact on patient recovery.

10.2 The Four Thematic Areas:

Promotion of Public Health for Scotland

Improving the health of the Scottish population remains one of the major challenges facing policy makers, educators and clinicians. Organisations in Scotland and the UK such as Health Scotland, the Royal Society for the Promotion of health and the Faculty of Public Health, already exist to promote continuous improvement in human health world-wide through education, communication and the encouragement of scientific research.

Public education and engagement with healthy lifestyle choices is key to improving the health of the nation over time. By using the latest interactive imaging, the Network can promote engagement with the health message, and enhance understanding. This will appeal particularly to the younger generation who are naturally comfortable with 3D interaction through computer games.

Visualisation techniques offer an opportunity to communicate clearly to the general public that preventative care and precautions can be taken to reduce, minimize, control or avoid a range of potential diseases resulting from addictions, poor diet, weight loss/gain or levels of fitness. They can play a supportive role in both reducing potential problems in later life and raise awareness of lifestyle behaviours and their impact on health.

The downstream implications of reducing the impact on the NHS could be potentially significant allowing Scotland to improve its rating in the European health tables.

Training and Anatomical Teaching

Digital imaging has been able to transform the way in which we obtain and interpret x-rays and scans of the body. However, interpretation of these scans is not easy and must be made in the context of expert anatomical knowledge. Disciplines such as radiology and surgery demand high-level skills based on undergraduate and postgraduate skill acquisition.

In recent years, the nature of undergraduate teaching has changed in response to increased time pressure between subjects and growing class sizes. The amount of face-to-face teaching in core subjects such as anatomy has been heavily reduced. As practical resources have become pressurised, increasingly, medical teaching has revolved around personal study and internet resources. This, combined with the reduced availability of human cadavers under a new EU directive on the use of chemicals in treating cadavers, has led to some concern about the future of traditional teaching methods.

A number of technological advances have been identified which can contribute to surgical training and reduce dependence on cadavers: restructured animal tissue models, synthetic tissue models, and virtual reality simulation. However, restructured animal tissue models require considerable technician resource, and thus preclude adoption on a large scale, whilst the simulation of complete operations on synthetic tissue models is limited in scope and very expensive.

Thus, VR is a realistic proposition for the training of both generic and surgical skills. Bertie Woods, Her Majesty's Inspector for Anatomy for Scotland and a member of the Network Board, believes the Government should be encouraged to fund the teaching of anatomy in 3D.

Recent developments in digital visualisation can revolutionise anatomical teaching with a return to the virtual 3D body. Current 2D computer based systems are limited in their usefulness and have had a minimal impact on teaching. A combined approach by visualisation experts, educationalists and clinicians within the Network, can address this problem.

3D interactive digital imaging would allow the basis of anatomical knowledge to be taught using real 3D perspectives with real-time or accelerated dynamic representation of physiology and disease in action. Students of all levels and disciplines would be able to interact with, explore and discuss anatomy as they once did in a wet lab, but in an accessible and timely fashion.

Gross anatomy coupled with informative animations demonstrating complex cellular biology and pathophysiological processes would provide an unrivalled research and teaching tool capturing the imagination of doctor and lay person alike. Such a resource, once developed, could be rolled out on a large scale, and could potentially simulate a range of pathologies.

The case studies completed by the Network have demonstrated the benefits of such techniques in understanding complex anatomy such as the Inguinal Canal and Lung Collapse, and in developing skills such as conducting a Lumbar Puncture. These benefits are already being harnessed in the development of new projects such as the Visualisation of the Anal-Rectal Junction and the Chest Drain Simulator, both funded by NES.

Surgical rehearsal and pre-operative planning

Digital prototyping and interaction with volumetric data in 3D with haptic devices is a very real possibility. Interactive digital applications can build on what has already been achieved in virtual colonoscopy and computer-aided pulmonary nodule detection to expand what is potentially the most exiting teaching tool and clinical aid within our immediate grasp.

Interest is also being shown in the use of visualisation techniques as decision-making tools for surgeons, particularly with regard to studies in psychological loading.

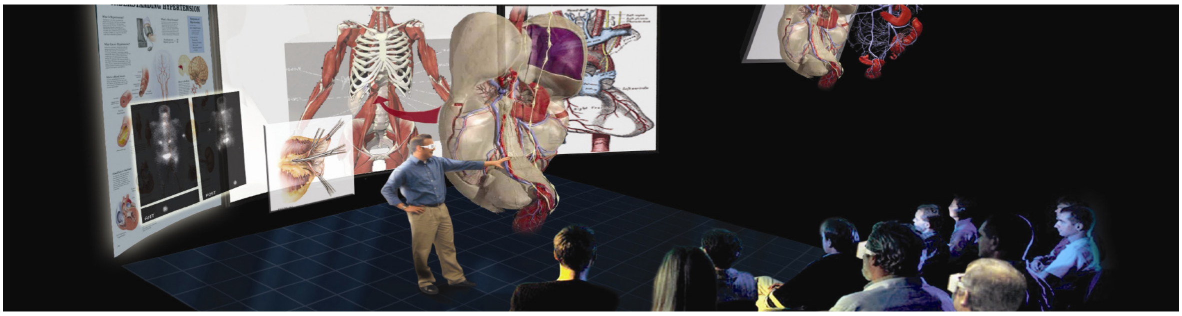
Post-care management

Modern medicine relies on a broad range of skilled professionals who must work together to ensure the best outcomes for the individual patient. Enhanced visualisation allows for interactive discussions between team members, the team and the patient.

Patients need to understand the procedures and treatments they are offered. Through 2D and 3D interactive imaging, information can be communicated clearly to the patient.

This could range from explanation of disease processes, a degenerative condition or everyday surgical procedures, post care management and recovery regimes. Considered application of such techniques could empower patients' decision making, and reduce their anxiety. A patient's understanding of the route to health has been found to have a positive profound impact on patient recovery terms.

Figure 15: Concept image showing 3D visuallisation in medical teaching.



10.3 Enhanced Case Studies
Considerable interest has also been shown in the further development of the five case studies described above, and on extending such techniques to other areas. Such development is likely to require full-time expertise and industrial collaboration.

11 Recommendations and Future Plans

The Scottish Medical Visualisation Network Feasibility Study has successfully established a partnership between a large number of medical professionals, researchers and students across Scotland and reached out to partners in the rest of the UK and internationally.

To ensure this momentum is maintained, the following recommendations are made.

- The network should be expanded to encompass all medical disciplines in Scotland.
- Nurture medical student involvement in the formation of a dedicated interest group within the Network.
- Build upon the large body of expertise across the disciplines within the Network to attract significant projects with international visibility, putting Scotland to the forefront of medical visualisation research.
- Develop the case study models. In particular, an approach needs to be identified to develop the inguinal canal and lung collapse studies to the next level.
- Strengthen the link to key industrial players to commercialise the intellectual property developed within the Network.
- Establish the DDS as a Hub to undertake research development activities and disseminate visualisation technology. This Hub will share data and disseminate research outputs to five other centres across Scotland.

Figure 16: Still from a 3D animation of proposed Lab1 at Pacific Quay – new premises for the Digital Design Studio from 2009.

The Network has already succeeded in bringing together key persons and organisations across Scotland. With infrastructure and research funding in place, the Network can have the capability to establish Scotland as a world leading centre in medical visualisation both academically and commercially, by providing the tools that practitioners need.

12 Financial Plan for Future Development

A four-year financial plan has been created that will provide the necessary research and development capability to the Network whilst it works towards becoming financially self sustaining.

It is essential that the Network develops a core research team appropriately equiped. This will allow Professor Paul Anderson to lead two research programmers and two 3D modellers to develop the definitive 3D Digital Interactive Human. This will provide an anatomically accurate dataset from which teaching materials, training simulations and commercial products can be developed. This ambition is at the heart of the Network's current activities and future aims as outlined in Sections 9 and 10.

The research programmers are expected to be of post-doctoral standing and with a research track record in either medicine or visualisation.

The highly skilled 3D modellers will have expertise in the latest modelling techniques and will be trained to use highly specialised 3D digital laser scanning equipment. They will work closely with a range of medical disciplines across Scotland.

A full-time administrator is required to coordinate the Network including membership

Item	Description	Cost
Directly Incurred Costs		
Researchers/Programmers	Direct cost of 2 researchers based at the DDS for four years including superannuation and NI.	£380,346
Modellers	Direct cost of 2 dedicated modellers for four years including superannuation and NI.	£311,323
Administrator	Direct cost of a full-time administrator for four years	£108,282
Travel	Budget dissemination of research including major European and International conferences.	£25,235
Other	Equipment, tools, technologies and software for case studies, 2 workshops per year and a marketing budget.	£322,538
Directly Allocated Costs		
Management Costs	Services of Professor Paul Anderson (0.5FTE) to direct the project for four years.	£186,982
Indirect costs		
Estates	Rates set by Institution; calculated on FTE	£171,167
Indirect	Rates set by Institution; calculated on FTE	£675,407
Total Expenditure		£2,181,280

issues, web content management, marketing, organising meetings of the advisory committee whilst organising and coordinating two workshops per year.

A travel budget of £25,235 is included as it is anticipated that the research carried out by this team will result in high quality research outputs which will be disseminated at the highest level. This will involve the team travelling to conferences all over the world approximately 10 in UK/Europe and 10 outside of Europe are anticipated over a four year period.

Specific equipment required includes a highly specialised portable 3D digital laser scanner. This is required to provide real-time measurement data and is capable of scanning parts of the body to sub millimetre accuracy. It will allow the team to produce a high quality anatomically accurate dataset with photo accurate texture maps not currently available anywhere. The scanner is expected to cost £117,500K.

High end computers with the latest software and a base 3D female model will also be required. Software will need to be updated yearly; it is estimated that initial costs and upgrades will be around £105,163K.

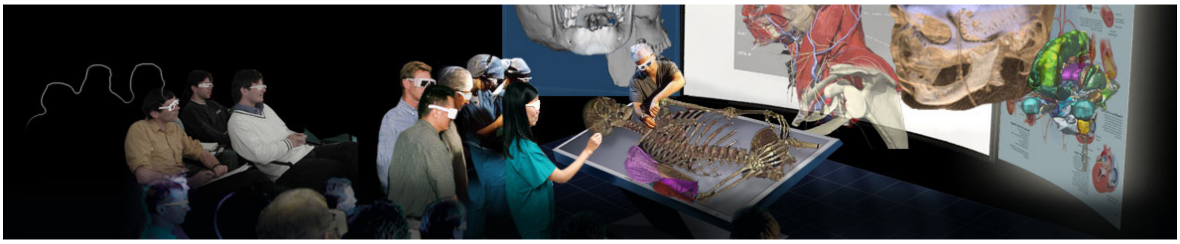
£29,375K has been included as a marketing budget, £11,750 for web site hosting and development, and £70,500K for the cost of hosting eight workshops over four years at national level for around forty delegates. The workshops will be used as a means to disseminate the research to the Network and get their feedback and input to further research.

The success of the Scottish Medical Visualisation Network will require a committment from Professor Paul Anderson equvalent to 2.5 days per week.

It is hoped that this dedicated research team will be located at the new DDS facility at Pacific Quay in Glasgow. Negotiations are also ongoing for at least three sponsored Fellowships across medical disciplines. The Network's first sponsored PhD student will start at the Digital Design Studio in October 2008.

End of Report

Appendices



Professor Paul Anderson BA(Hons) MDes(RCA) FRSA FRGS
Paul is the Director of the Digital Design Studio, which he established in 1997. He has an international profile in digital visualisation and interaction research concerned with fundamental human computer interface issues, particularly those associated with 3D interfaces, haptics and gesture-based interaction. He has won major research funding from the EU, EPSRC, NESTA, Scottish Funding Council and Scottish Enterprise. His research interests are focused on medical, automotive and defence fields. He has collaborated with a number of world-class research organisations, and has published internationally on the subject of digital visualisation and interaction. Paul leads the Scottish Medical Visualisation Network in partnership with David Rowley.

Professor David Ian Rowley B Med Biol, MD
David is Professor at the University Dept. of Orthopaedic and Trauma Surgery, Ninewells Hospital and Medical School, Dundee, Director of Education, Royal College of Surgeons of Edinburgh and Visiting Professor of Surgical Education, University of Edinburgh. He is a lower-limb construction surgeon now entirely in the elective field and runs a global audit and outcomes unit assessing the long term results of hip and knee replacements. He has a particular interest in knee arthroplasty and foot surgery and biomechanics. He has carried out infection studies for the International Committee of the Red Cross and undertaken several field missions. David leads the Scottish Medical Visualisation Network in partnership with Paul Anderson.

Professor Philip Cachia MD FRCPE FRCPath (haematology)
In 2004, Philip was appointed Postgraduate Dean for East of Scotland Deanery at Ninewells Hospital and Medical School in Dundee. The Deanery maintains close contact and working relationships with GP and Dental colleagues who are located at Tayside Centre for General Practice and Dundee Dental Education Centre respectively. Previously he was a consultant haematologist in Tayside involved in training and education as specialty advisor for haematology, regional advisor for the Royal College of Pathologists and Postgraduate Tutor with responsibility for SHO training in Tayside.

Dr David Chanock MBChB FCRad(D) SA.
David was educated in South Africa and studied radiology in Durban. He emigrated to Scotland in 1997 and has been working there as a Diagnostic Radiologist since his move. He is a general radiologist with an interest in cross sectional imaging. He has a keen interest in teaching and is the Acting Academic Sub-Dean for Glasgow University at Ayr Hospital and the NES Foundation Tutor. He is an examiner in the final year medical examinations at Glasgow University and is on the steering group of the MS Managed Clinical Network.

Mr Bill McKerrow MBChB MRCGP (exam) FRCS Ed & Glas.
Bill is a consultant in ENT for NHS Highland based at Raigmore Hospital, Inverness, with a special interest in surgery of the middle ear and surgery of the salivary glands. He has published widely within the specialty, with particular relevance to the effectiveness and safety of surgical interventions for common ENT disorders. He is involved in undergraduate and postgraduate medical education, examining for the Royal Colleges of Surgeons of Edinburgh, Glasgow and Hong Kong, and for the Intercollegiate Board in Otolaryngology. Appointments relevant to medical education include the Chair of Specialty Advisory Board in Otolaryngology of the Royal College of Surgeons of Edinburgh, and membership of the Specialty Advisory Committee in Audiological Medicine. He has held a number of advisory posts within his field.

Professor Ian G. Parkin MBChB
Ian qualified in medicine in 1975 but after pre- and post-registration medical and surgical positions, chose to follow a career in anatomy, becoming professor of applied clinical anatomy, University of Dundee and Royal College of Surgeons of Edinburgh, in 2005. He is a Fellow of the British Association of Clinical Anatomists and Honorary Fellow of the Institute of Anatomical Sciences. His expertise includes the delivery of three-dimensional, functional and clinically relevant anatomy to undergraduate medical students and postgraduate trainees.

Professor Bertie Wood BSc (Hons) MB ChB
Bertie is HM Inspector of Anatomy for Scotland. He is an Edinburgh Medical Graduate who went on to become a Consultant Physician (FRCP Ed & Glasgow) in Perth from 1972-92 latterly as Deputy Director of Postgraduate Medical Education in Dundee. He then went to Aberdeen University as Postgraduate Medical Dean for North-East and North Scotland, and as a Professor of Medicine and Hon Consultant Physician. He was Lead Dean for Psychiatry for the UK. He became Hon FRCS (Ed) in 1995 and Hon FRCPsych in 1999. He retired from his Chair in 1999. He was a Councilor of RCP Ed from 1990-92 , College Dean from 1992-5, Treasurer of the College from 2000-2003, and is presently a Trustee of the College. He has been a Member of Council of Medical & Dental Defence Union of Scotland since 1989 and is now a Member of the MDDUS Board of Directors.

Dr James A Miller,
James Miller is Chief Executive of the Royal College of Physicians and Surgeons of Glasgow. James began his career as a student nurse in Edinburgh in 1983. After qualifying in 1986 he worked in a number of clinical posts before becoming involved in education, R&D and quality management in Edinburgh. In 1992, James moved to a hospital in West Lothian where he held a variety of posts including, Deputy Director of Nursing, Senior Nurse Manager and General Manager. Moving to Glasgow in 2001, James took up a General Manager's post at the Southern General Hospital where he stayed for a period of 4 years before taking up his current post in 2005 at RCPSG. Throughout his working life James completed three academic degrees in Dundee Institute of Technology (now Abertay University), as well as Napier (MBA) and Edinburgh Universities (PhD). James is also a Fellow of the Royal Society of Medicine

Dr Ben M Ward MBChB MRCS
Ben is Clinical Lecturer in the Department of Surgery at the University of Edinburgh leading 5th Year Undergraduate teaching in general surgery; he is undertaking a period of research towards an MD in surgical education. His interests include e-learning and Virtual Reality applied to surgical anatomy teaching and practice. He is part of the development team for a new online Masters degree in basic surgical sciences, the Edinburgh Surgical Sciences Qualification. He is a member of the ESSQ content and assessment groups and is particularly interested in online case-based learning. He has published internationally on behalf of the Scottish Medical Visualisation Network and is a Board member and lead researcher for the Network.

Dr Vassilis Charissis BSc(Hons) MPhil PhD
Vassilis specialises in the design and evaluation of human-machine interfaces in automotive and medical fields, and is currently developing a novel HCI interface for anatomy courses and surgical rehearsal through VR technology. He is a member of IEEE Computing Society, IEEE Intelligent Transportation Society and Society of Automotive Engineers (SAE). Vassilis has published internationally on behalf of the Scottish Medical Visualisation Network and is a lead researcher for the Network.

Linda Brady MSc FIBMS CSci MRSC CCHEM
Linda is a Fellow of the Institute of Biomedical Sciences and a chartered chemist. She has been involved in many research projects throughout her varied career in the NHS, the Water Industry and Academia. Linda is Co-ordinator of the Scottish Medical Visualisation Network. She is particularly responsible for membership issues.

Vivienne Blackhall
Vivienne is a medical student from the University of Glasgow, currently in her fourth year of study. She graduated last year with a BSc (MedSci) in Psychological Medicine; her dissertation examined obsessional symptoms in the puerperium. Vivienne is particularly interested in surgical and psychiatric specialties. As a committee member of the Glasgow University Surgical Society (GUSS), she is involved in organising and hosting surgical lectures and surgical skills training days for medical undergraduates. The GUSS committee also organise fundraising events for various surgical charities.

Published Papers:

V. Charissis, B. M. Ward, M. Naef, D. Rowley, L. Brady, and P. Anderson, (2008), An Enquiry into VR Interface Design for Medical Training: VR Augmented Anatomy Tutorials for Breast Cancer, in Proceedings of IS&T/SPIE 20th Annual Symposium of Electronic Imaging, Science and Technology, 26th -31st January, San Jose, California, USA.

B. M. Ward, V. Charissis, D. Rowley, L. Brady, and P. Anderson, (2008), An Evaluation of Prototype VR Medical Environment: Applied Surgical Anatomy Training for Malignant Breast Disease, in Proceedings of the International Conference of Medicine Meets Virtual Reality 16th (MMVR 16th) , 30th January- 1st February, 2008, Long Beach, California, USA. / publication awaited in Stud Health Technol Inform (2008)

B. M. Ward, V. Charissis, I. Young, D. Rowley, O. J. Garden, (2008), Surgical VR Training Environments: An Inquiry Into the Application and Validation of 3D Volumetric Anatomy Tutorials for Operative Surgical Training, in Society of Academic & Research Surgery, Annual Conference, 9-11 January, Botanical Gardens, Birmingham, UK.

B. M. Ward, V. Charissis, I. Young, P. Anderson, D. Rowley, (2007), Surgical Education: Applied Virtual Anatomy: Can Virtual Reality Augment Postgraduate Anatomy Teaching?, in School of Surgery Day, Department of Surgery, Edinburgh University, 28 November, Royal College of Surgeons of Edinburgh, Edinburgh, UK.

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V. Charissis, B.M. Ward, S. Sakellariou, D. Chanock, D. Rowley and P.Anderson, (2008), Medical Visualisation, Augmented Reality and Anatomy Training: An Intuitive Approach of Visual Arts and Medicine, Fifth Annual Meeting of the Association for Medical Humanities UK (AMH 08), 8-9 July, Glasgow, UK

D. Chanock, V. Charissis, B.M. Ward, L. Brady, and P. Anderson (2008), Enhanced 3D Visualisation: Augmenting Musculoskeletal Ultrasound Training, in proceedings of the United Kingdom Radiological Congress (UKRC 2008), Birmingham, UK.

B.M. Ward, D. Chanock, V. Charissis, L. Brady, and P. Anderson, (2008), Interpreting Lung Collapse: A Randomised Controlled Study into the Impact of Three-Dimesional Animation, in Proceedings of the United Kingdom Radiological Congress (UKRC 2008), Birmingham, UK.

An Enquiry into VR Interface Design for Medical Training: VR Augmented Anatomy Tutorials for Breast Cancer

V. Charissis[1], B.M. Ward[2], M.Naef[1], D. Rowley[2], L. Brady[1] and P. Anderson[1]

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ABSTRACT

This paper presents an initial study exploring and evaluating a novel, accessible and user-centred interface developed for a VR Medical training environment. In particular, the proposed system facilitates a detailed 3D information exchange, with the aim of improving the user's internal 3D understanding and visualisation of complex anatomical inter-relationships. In order to evaluate the effectiveness of the proposed VR teaching method we developed a female 3D model under the guidance of Consultant Breast surgeons with particular emphasis given on the axilla section. In turn we commenced a comparative study between PBL tutorials augmented with VR and the contemporary teaching techniques involving twelve participants. Overall the paper outlines the development process of the proposed VR Medical Training environment, discusses the results from the comparative study, and offers suggestions for further research and a tentative plan for future work.

KEYWORDS

VR Interface, Medical Visualisation, Anatomy, Medical Education, HCI, Breast Cancer, Surgical Training, Haptics.

1. INTRODUCTION

This paper presents an initial study exploring and evaluating a novel, accessible and user centred interface developed for a VR Medical training environment. In particular, the proposed system should facilitate detailed 3D information exchange, with the aim of improving the user's internal 3D understanding and visualisation of complex anatomical inter-relationships. Evidently, recent studies advocate the benefits of VR training methods, which can provide beneficial outcomes by shortening the learning curve [1]. Furthermore complicated anatomical issues can be visualised intuitively by a VR interface, which does not have any physical constrains [2]. Hence it is possible for the user to interact freely with a volumetric 3D model, selecting their own number of infinite viewpoints, a factor suggested to be central in spatial anatomical understanding [3]. In addition the importance of facilitating a balanced deep learning approach including visualisation skills has been highlighted [4].

It is recognised that undergraduate anatomical training has changed in recent years. The availability of cadavers to undergraduates has significantly decreased. In recent years, increasing student numbers and pressures from a growing undergraduate curriculum has resulted in a decimation of students' exposure to cadaveric material and a reduction in total anatomical teaching [5]. It is suggested that current medical and surgical trainees require anatomical resources that are convenient and adaptable to desired educational content and techniques [6, 7].

2. EDUCATIONAL MODEL

Recently there has been increasing interest in contextual situated learning in all disciplines, especially those requiring the application of integrated complex knowledge. A natural extension of the constructivist and situated approaches is the activity-based approach [8], where instructors frame the desired outcomes in terms of knowledge, attitude, skill and behaviours and design the learning activity to facilitate the active internalisation of different types of knowledge and meta-cognitive processes.

Medical Educationalists have become increasingly interested in the inherent opportunities that these techniques offer, in particular when knowledge and skills must be demonstrated perfectly in high stakes situations and challenging social environments. To this end there have been attempts to produce 'thickly authentic' interactive learning techniques to allow knowledge, skills, behaviours and reasoning to be learned in a clinically useful and therefore relevant manner [9]. These simulations also allow the student to fail safely, gaining from the learning experiences of failure with no risk to the patient. This approach has been mirrored by computer educational theorists, describing the role 'epistemic gaming' [10] i.e.: highly interactive problem based resources placed firmly in a realistic professional context. These two approaches highlight a growing area of interest in medical training; structured, contextualised learning in a virtual or 'real-world' environment that mirrors contemporary or professional challenges.

However within medical educational literature there remains doubt regarding the educational benefits of 3D visualisation (stereoscopic) vs. 2D applications in teaching spatial anatomy and operative procedure. Existing publications regarding the advantages of 3D display and rendering look mainly at rotational 2D representations of 3D anatomy in core undergraduate teaching. Stereoscopic projection has been demonstrated repeatedly to improve learning outcomes in training outside medicine [11, 12]. Additionally the specific advantages of free interaction with rotational models when learning complex 3D anatomy has been identified [3]. Also the importance of understanding the role of student spatial-skills has been identified [13]. Currently many described studies exist in isolation from existing educational approaches and are de-contextualised from practical implementation. It was an aim of the inquiry to look at the use of 3D visualization as a resource for student-centred, situated, activity-based and activity-centred design [14] that could be implemented in surgical education.

Adhering to the aforementioned approaches we decided to evaluate the desired learning outcomes for surgical trainees in the subject domain of the clinical and operative management of advanced breast cancer. In association with the Edinburgh Breast Unit and utilising the transitional intercollegiate Membership of the Royal College of Surgeons (MRCS) examination we illuminated the key knowledge required. This was identified in terms of applied basic science, clinical principles and knowledge of operative procedures and protocol. In addition we identified the key skills and processes involved in sentinel node biopsy and the operative approach to axillary clearance. Additionally we developed a series of common case vignettes to create subject interaction and therefore explore reasoning. These principle goals were then mapped to situated activities which formed the basis of the design requirements for the structured tutorials and the semi-immersive VR application.

The primary goal was to place the student in a situation in which they experienced 'thickly authentic', situated learning in the context of a tutorial with a surgical trainer. A framework for this was produced and the VR system described below designed to meet these goals. It was important that an integrated approach was taken in all aspects of design, in order that we could create a design method embracing surgical educational needs, accurate anatomical representation and seem-less information transfer within the described educational model.

3. VR REQUIREMENTS

The aforementioned contemporary issues in medical training fuelled the development of the VR environment, which was based in the existing Digital Design Studio VR facilities. The particular system is developed around a Fakespace Immersive Workbench and entails real-time visualisation, gesture interaction with tactile feedback (CyberTouch™ sensored glove) and 3D sound as depicted in figure 1(a,b). Its semi-immersive design is particularly valuable in assisting with small group tutorial requirements.
Although the particular Workbench was initially developed for automotive engineering evaluation [15] it was found that the table-design of the installation offered an intriguingly similar position and dimensions to an operation table or an examination bed. Hence the existing VR and haptic technology was repositioned in order to enhance this feeling, replicating as much as possible the position of a cadaveric examination.

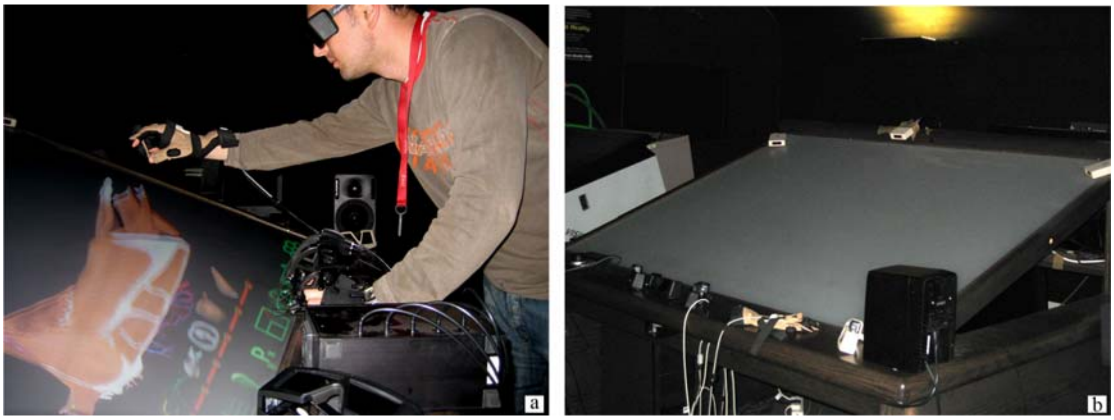

Figure 1: (a) Haptic interface demonstration for the manipulation of the VR human section
(b) The Fakespace Immersive Workbench with the CyberTouch™ sensored glove.

The virtual visualisation was achieved with CrystalEyes shutter glasses. We opted for this type of glasses as it was essential in this setting to provide the trainee and the trainer to see themselves and other members of the group as well as the model. In contrary fully immersive systems using head-mounted displays present a fully virtual environment which lacks the interactivity between the users during anatomy teaching or the trainee/trainer discussion of surgical rehearsal.

A minor pitfall of the system is that only one pair of glasses could be tracked by the table-sensors (typically the person using the haptic glove). Hence the rest of the viewers should be positioned as close as possible to that user (with the tracking-glasses) in order to have minimum visual distortion. However we intend to minimise the visual distortion experienced by the users with the non-tracking glasses by the development of a new VR facility with a substantially larger viewing surface.

The "physical" interaction between user and the VR model is enabled with the use of a tracked CyberTouch™ sensored glove with vibro-tactile stimulators on the fingers and palm. This glove can sense the bend and relative position of the fingers and thumb, allowing interaction via gesture; combined with tracking it can sense the hand's position in space, allowing the user to explore and manipulate the digital model directly in 3D space.

Additionally 3D spatialised auditory cues provide sound effects which signalise a variety of different actions. The depth perception is extensively investigated with sound moves in space appropriate to the manipulation of the model. Notably the initial system was developed on the SGI platform. However contemporary CPUs, graphic card accelerators and large capacity memory DIMMS made implementable the transfer to a high-end PC platform. As such, the prospective system's cost efficiency was reduced radically offering the ability for the research team to experiment in more complex interfaces, models and even consider the development of a mobile system..

4. CONTENT DEVELOPMENT

4.1. 3D Model Reconstruction

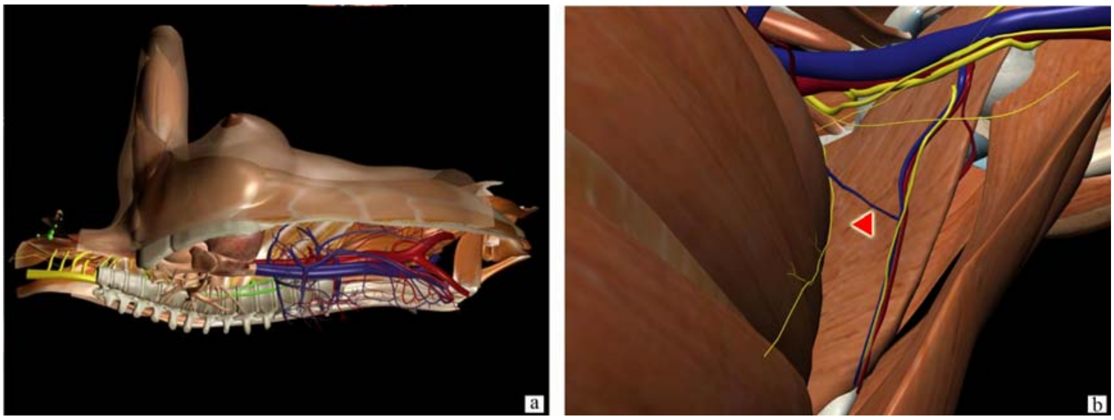

Figure 2: (a) Complete, detailed section of the female VR human body.
(b) Close-up of the 3D model with emphasis on the angular vein and inter-neural zone.

In order to evaluate the effectiveness of the proposed VR teaching method we developed a female 3D model under the guidance of Consultant Breast surgeons. Particular emphasis has been given to the axilla, its contents and surface markings. The nervous, venous, arterial and lymphatic systems were meticulously modelled to depict accurately the complex structures and their relationships as shown in figure 2. Notably the initial 3D human body data was developed with the use of CT and MRI scans. However the over-complex data had to be remodelled substantially in order to comply with the anatomical road-map required during the trainee test evaluation. The identical replication of details that present anatomical landmarks was of outmost importance for the successful conveyance of relevant information to the users. Additionally specific areas of the anatomy under investigation were elaborately developed with the constant input of information provided by the surgeons. Particularly the angular vein of the axilla, first described in 1993 [16]. This was introduced as it is a key surgical landmark in axillary clearance [17]. This exemplifies the importance of this collaborative methodology, and indeed the difference between taught and surgical operative anatomy.

In particular the three dimensional human model's complexity had to be restrained in order to comply with the maximum polygon-number computational ability provided by the customised personal computer. Therefore the model was further reformed and evaluated for optimum performance during projection and navigation. Interestingly the hierarchy and structure of the human model had to be adapted for the display and human computer interaction as well as for serving the examination process (i.e. questions sequence).

4.2 HCI Development

The interaction between the user and the system was investigated explicitly in order to facilitate the requirements for the anatomy teaching of the particular area. Therefore the overall HCI was tailored to simplify the examination of the human model.

The interface interactivity was pushed beyond traditional information and data visualisation by including real-time transparencies in specific sections and organs of the human body enabling the users to comprehend the spatial relationship between lymphatic, vein, and musculoskeletal parts of the body. Interactivity means design parameters can be changed using the same user interface used for the visualisation. In the case of the product model, this means that the user may pick and change objects in real-time. Furthermore these customised interactivities could carry auxiliary functions which might include predetermined or real time simulations for different types of surgical rehearsal. The current virtual model exemplifies such an interactive scenario, as it highlights the potential problems during the surgical rehearsal for a malignant breast disease operation. As the specific interface is under development we form a tentative plan of work in order to incorporate extensive functionality and artificial intelligence in the system, so as to offer various guidelines or suggestions to the user either for the learning anatomy or for understanding the procedures for specific surgical operations.

Incorporating multiple viewing alternatives (i.e. predetermined positions of the specific section) and defining objects or structural parts that can be changed interactively (i.e. pectoralis major and minor transparency) required equally custom-tailored models as well as appropriate interface development that could support such functionalities. Hence the content of the experiment was heavily supported and highlighted from the intuitive HCI design. To this end we consider that an innovative HCI design may be composed of similar interface elements but their re-arrangement and context should be customised heavily for serving different anatomical issues and surgical rehearsal cases. Hence finding ways to make such issues easily understandable from different medical practitioners is illustrative of our approach.

5. EXPERIMENT RATIONALE

The validation study is based around contemporary experiments described in the literature and includes refinements drawn from other group's experiences. In particular it was decided to assess both the quantitative impact on learning outcomes and explore qualitatively the user's experience of the VR interface, their interaction with the data and the perceived educational value of the application. The study design is essentially a comparative randomised control trial with pre- and post-intervention assessment utilising matched quantitative and qualitative instruments.

5.1 Subjects

The target subjects of the validation comprised postgraduate doctors with a declared interest in surgery and one to two years of clinical experience in the National Health Service (NHS). Currently all graduating medical students must complete two years of organised generic postgraduate training (the Foundation Programme) prior to competitive selection for clinical specialities. As part of this process it is important that they complete not only in the foundation programme itself, but also undertake external collegiate membership (entrance) examinations in their chosen discipline. The targeted learning outcomes in the study came directly from the intercollegiate MRCS, and so focused directly on this group. To this end we approached Foundation Year doctors within Scotland and asked for volunteers for the validation study. The response rate was high, as many were studying for surgical membership and saw the study as a route to structured teaching time (total 36).

Figure 3: Actual screenshot during the evaluation

The volunteers were pre-assessed for anatomical knowledge and prior experience of 3D rotational applications. Twenty-three met the predetermined criteria and twenty were selected. This produced a balanced group of trainees in terms of graduating university (Edinburgh, Glasgow, Dundee, Aberdeen), sex, experience and age. These were then randomised to two trial arms.

The subjects were all current trainees and it is for this reason (ie: rota commitments) that the final total sample size was twelve rather than twenty. This lead to a rather small group size, but was sufficient for this scoping study. This illuminates a major problem for similar studies in this group, and has lead to the concept of developing a portable VR test-bed that can be taken to regional training days and thus increase future sample sizes.

5.2 Experimental Methods

The FY doctors were randomised into two groups:

1. Structured tutorial (traditional resources)
2. Structured tutorial (proposed VR system)

The groups then undertook their respective tutorials at the Digital Design Studio, Glasgow. Both groups were time limited to 25 minutes and guided by the instructor to a identical pre-determined protocols. The tutorial format was activity-based and situated, i.e.: designed to prompt the student into interaction with the real world/VR environment facilitated by the instructor.
The protocol was designed using operative expertise in collaboration with Consultant Breast Surgeons. The learning objectives included surgical anatomical knowledge, the principles of surgical management and operative treatment.

Attempts were made to control variables. All tutorials were undertaken in the same 2 month period the same with the identical protocol, model, equipment and instructor. The tutorials were repeated several times with the maximum of two subjects taking part at any time. Immediately after the tutorial all trainees were debriefed using identical instruments.

5.2.1 Qualitative Method

The subjects were debriefed using a forty point subjective user evaluation questionnaire. Additionally open questions were used to illuminate development issues and direct further work. The questionnaire used a nine point Likert scale, allowing a neutral position. The questions were grouped to explore the interface utility, interactivity, efficiency, subject engagement, and perceived spatial learning. Internal consistency was measured using Cronbach’s alpha, responses were analysed by group and individual means.

5.2.2 Quantitative Method

Multiple Choice Questions (MCQs) were used to debrief all subjects. A set of twenty questions, both True/ False and common stem questions were used. The questions were structured into three groups. Respectively these explored spatial anatomy, the surgical approach and clinical principles.
Each group was analysed finding total and question group means, standard deviations and confidence interval ($P<0.05$).

In this paper we were particularly interested in the way the FYs perceive the system’s interactivity and how that facilitated contextual spatial learning. Additionally we sought quantative information in order to ensure quality measurement and assurance (i.e.explore the possibility that the system damages learning outcomes). As such the quantative results were reassuring in that they indicated that there was little overall difference between the MCQ scores in either group (VR goup mean **61.25** vs Traditional group mean **60.41).**

6. RESULTS

6.1. Thematic Analysis

Two major themes pre-dominate the responses to the open questions. These themes support the findings of the user questionnaire. The first and most prevalent was exhibited in opposition between the groups and regarded engagement with the activity-based scenario. It is interesting to note that in the VR group students repeatedly commented on the 'immersion' and 'engagement' when speaking about their experience of the tutorial. One student said simply:

'I found it really easy to get into it; it brings the anatomy to life, very like the dissecting lab'

This was almost reversed in the traditional group, where several group members commented on the difficulty they experienced in 'getting into it", this is one example:

'it reminded me of role playing, which I was never very good at as an undergraduate. '

It is interesting to note there were no complaints of difficulty engaging within the VR group.

The second most theme related to the subjects confidence in their understanding. It is quite telling that both groups felt the tutorial enhanced their learning of anatomy, but when asked about their confidence that they had learned accurately, a common response in the traditional group was that they were sometimes unsure if they had communicated their doubts clearly:

'it was difficult. I was asked a question, and I don't know if we were talking about the same thing.'

In contrast members of the VR group found that communication with the trainer was enhanced and that individual misconceptions were exposed:

' If its in front of you, you can both see. He (the instructor) can see if you are wrong. '

It is interesting to note that both groups perceived the same tutorial in very different ways, despite the shared protocol. The results appear to indicate strongly that the ability to share the 3D experience of the anatomy between the trainer and trainee is important, as the analysis of the questionnaires depicts in figure 4.

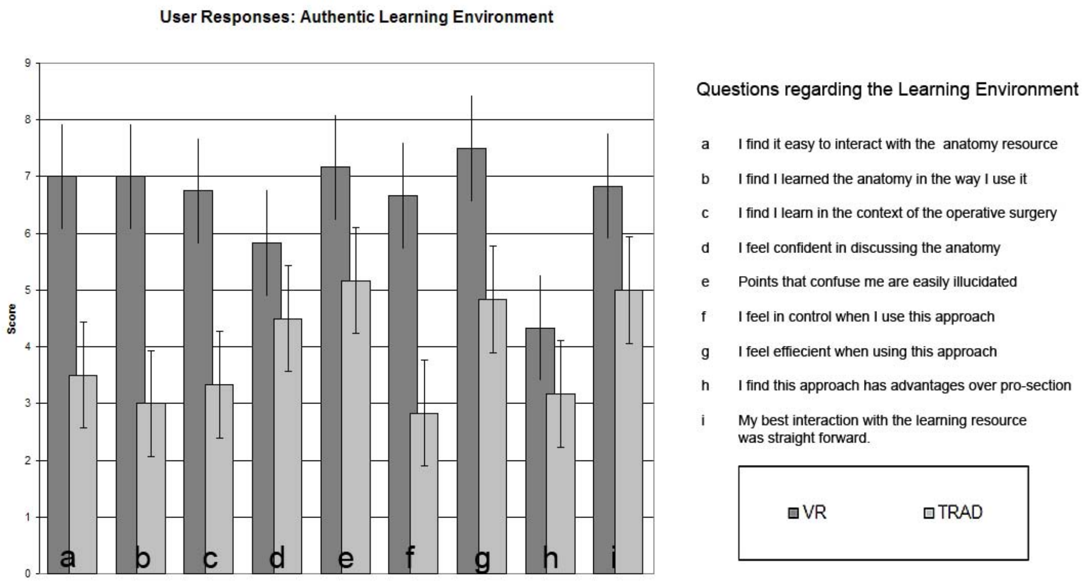

Figure 4: Comparative results between VR teaching environment and the traditional techniques.

6.2 Qualitative Analysis

The above results present a preliminary but, nonetheless, informative assessment of how the VR learning environment augments contemporary teaching methods. Interestingly this small evaluation demonstrate the potential impact of an accurate model displayed interactively via VR (figure 4).

Notably, the use of the VR human body was preferred overall amongst the trainees in the two groups. Specifically, the majority of the participants found the VR anatomy considerably easier to interact with and understand as questions (a)and (b) shown respectively. Evidence collected also suggests that VR augmentation also enguages and empowers the student as they percieve increased control (f), Additionally the results show that with the use of VR the student is not only a receiver of information but he/she is also enabled to interact in real-time with the given data. This would seem to reflect the advantages of situated, activity-based approaches. Additionally student in the VR group describe enhanced communication with their instructor (e) Also of note the students seem to express increased confidence in the accuracy of their knowledge (g).

Finally the results obtained from question (i) indicate that the functionalities of the human computer interaction (HCI) was accumulated very quickly. This can be attributed to the design of the interface as well as the familiarity of the contemporary students with complex operating systems throughout their daily life.

7. CONCLUSIONS

This paper describes the rationale and development process of a user-centred interface designed for a VR Medical training environment. The system was evaluated in a comparative study against the traditional anatomy teaching techniques. Although this is a preliminary study we tried to identify the potential positive elements of a VR environment and highlight the potential pitfalls. The system was perceived unexpectedly well from the users mainly because of the ability to investigate the human body without any physical constraints. However the complexity of the haptic interaction renders the system immobile, hence minimises the number of users that could visit the facilities for further training. To this end we currently investigate a mobile solution that incorporates “off the shelf” data-manipulating devices (i.e. Xbox or Playstation controllers) and we plan in the near future to repeat our user-tests with these devices and larger groups.

Finally, our tentative plan for future work includes further development of the VR interface to include practical pre-operative surgical rehearsal for core surgical procedures.

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An Evaluation of Prototype VR Medical Training Environment: Applied Surgical Anatomy Training for Malignant Breast Disease

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Abstract. This paper presents an enquiry into the suitability of Virtual Reality (VR) technology as the principal training method for applied surgical anatomy. In this work we present the development of a prototype VR medical training environment and the evaluation results of preliminary trials aiming to identify the effectiveness of the system in the subject domains of anatomy teaching and surgical rehearsal, whilst acknowledging current training requirements.

Keywords. Anatomy, surgery, breast cancer, tutorial, semi-immersive, HCI.

Introduction

Recent studies have suggested that VR training methods shorten learning curves [1]. In addition current changes in anatomy and surgical training demand flexible availability of teaching resources. Increasing student numbers and the pressures from a growing curriculum have resulted in a reduction of effective anatomy teaching time and the accessibility of cadaveric materials to trainees has decreased [2]. In contrast educational research highlights the importance of visualization skills in anatomy learning [3]. Hence a cost effective, on-demand solution could be offered by developing a “VR cadaver”. Contemporary attempts to train medical staff using 3D models were encouragingly positive [4, 5].

However previous studies involving 2D web applications and complex interfaces fuelled the development of a VR system emphasizing an interface that could effectively convey information to the user. Hence we developed a detailed 3D model to facilitate training. The model’s complexity is adjustable to student requirements and is easily focused on specific training goals. Additionally, utilizing haptic interaction could improve the user’s spatial awareness of complex structures [6].

The hypothesis behind this study suggests VR interfaces and holographic human body representation could convey appropriate information to the students in an accessibly interactive manner compared with available teaching resources [7].

1. Simulation Methodology

To evaluate the effectiveness of this tool we employed the VR facilities at the Digital Design Studio [8]. Our system incorporates real-time visualisation, gesture interaction with tactile feedback (CyberTouch™ glove) and is based on the Fakespace Immersive Workbench. We opted for this configuration for three reasons. i) The “Workbench’s” table-projection surface resembles a surgical table. The trainees therefore experience contextual immersion. (ii) This semi-immersive system projects the 3D model into the user’s space, allowing them to see themselves and other group members alongside the model. (iii) The interface is fully customizable to facilitate explicit utilities along with standard navigation. The training, evaluation and assessment materials were provided by the Royal College of Surgeons, Edinburgh. Guided by Consultant Breast surgeons we modelled a 3D representation of the torso, axilla and its contents. The nervous, venous, arterial and lymphatic systems depict accurately anatomical relationships. The detail level focused on the intercollegiate Membership of the Royal College of Surgeons (MRCS) transitional curriculum[9]. Our research focused on Human Computer Interface (HCI) and VR simulation development (Figure 1). The main objective of this activity-centered study [10] was to enhance and accelerate the assimilation of knowledge of surgical anatomy.

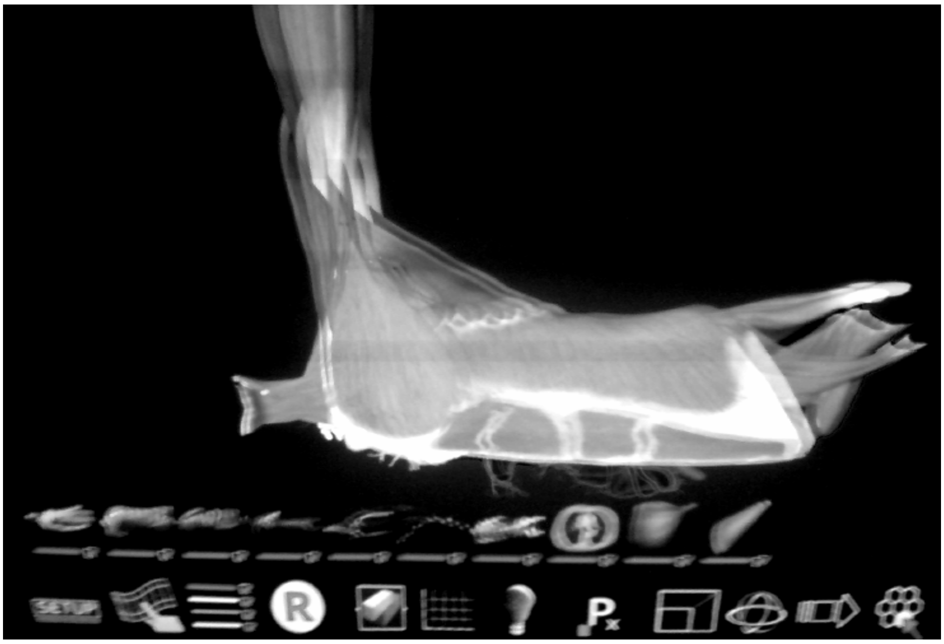

Figure 1: Screenshot from the VR interface.

2. Evaluation & Results

Twelve Postgraduate trainees (FY2) were selected and split into two arms. Both were objectively pre-assessed to ensure suitability. The first underwent a structured PBL anatomy tutorial augmented with the VR model (Figure 2). The second group took part in the same tutorial using traditional resources. The tutorials focused on applied surgical anatomy relating to malignant breast disease. Both arms completed a subjective user evaluation questionnaire and a multiple choice assessment structured to test candidates internal spatial understanding of common surgical approaches and complex anatomical relationships [11]. The subjective evaluation was an adapted Questionnaire for User Interface Questionnaire (QUIS) exploring perceived usability, engagement and value [12].

The results were processed to compare each arm against group and individual means, given standard deviations and confidence (p value 0.05). Grouped questions were compared to illuminate trainee's perceptions of their individual engagement, modified learning approach and internal 3D assimilation.

Table 1: Analysis of mean results of structured QUIS items exploring acquisition of 3D understanding.

3D Internalization	Question 1: I find I learn immediately as internal 3D model.
	Question 2: I find I have to work hard to create a 3D model internally.
Error Recognition	Question 3: I find I recognize mistakes in my understanding easily.
	Question 5: This approach makes me confident about my learning.
Communication	Question 4: I find it easy to discuss the anatomy with my facilitator.

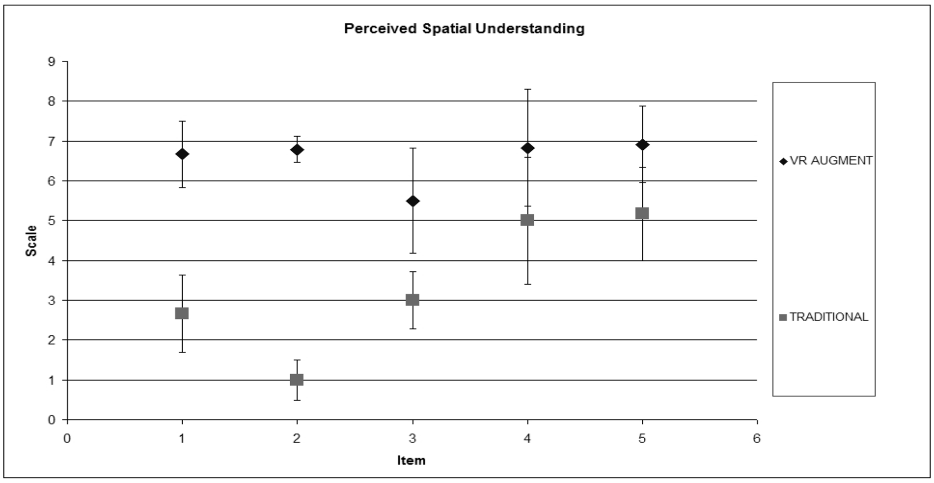

Figure 2: Analysis of mean results of structured QUIS items exploring acquisition of 3D understanding.

Figure 2 presents comparative data demonstrating whole group means attributed to items which explored spatial knowledge transfer and the facility each approach demonstrated in aiding the synthesis, appraisal and amendment of imparted anatomical relationships. Statistical analysis was limited by the small group size.

In addition item groupings demonstrated improved engagement, a reduced reliance on tutor support and higher levels of efficiency and accuracy in learning.

Significantly the VR arm showed higher scores in questions testing spatial relationships, specifically in the context of surgical approaches. However, overall results were balanced between the two approaches, with no significant difference between mean group performances. Figure 3 illustrates the mean results of MCQ questions structured to be "far", i.e.: requiring spatial understanding rather than direct interpretation of provided resources. In turn the same figure presents the similar overall performances (VR 61.25%, Traditional Resource 60.41%) between the two groups.

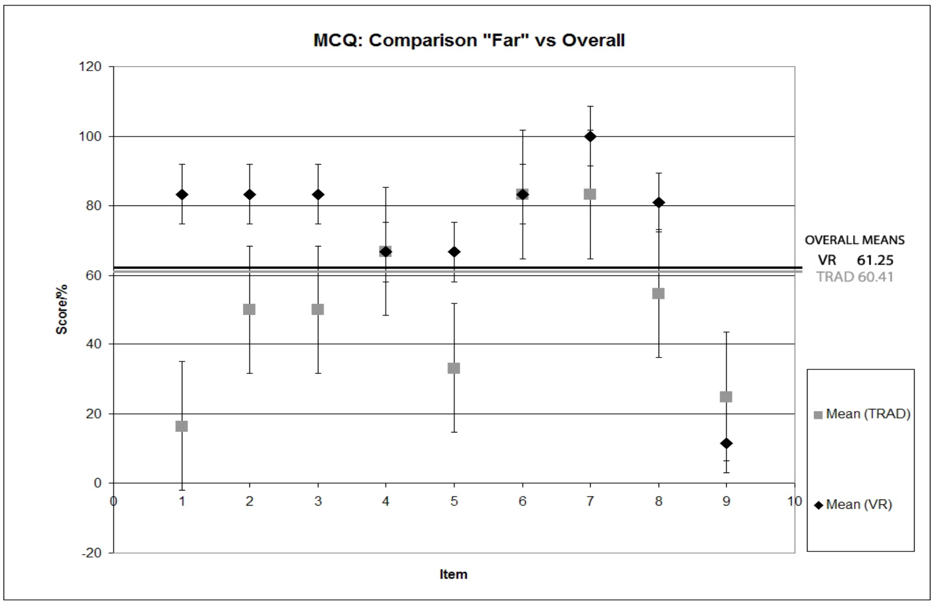

Figure 3: Mean results of "Far" MCQ items contrast with similar overall performance.

Interestingly the structured qualitative interview reinforced the positive outcomes of the MCQ "Far" results. Themes developed within the answers reflected trainee's enhanced confidence in their anatomical knowledge when able to interact and explore the VR models during the tutorials. Additionally the exploratory attribute of the system was commented upon. This was reported to enable users to illuminate areas of weaker understanding and fill knowledge lacunae.

The interviews also revealed recurring themes relating to the user interface. User's varied in the ease with which they were able to utilize the haptic tools, note that the specific interface was designed specifically to facilitate the preliminary investigation and it is our intention to incorporate users' feedback into future versions.

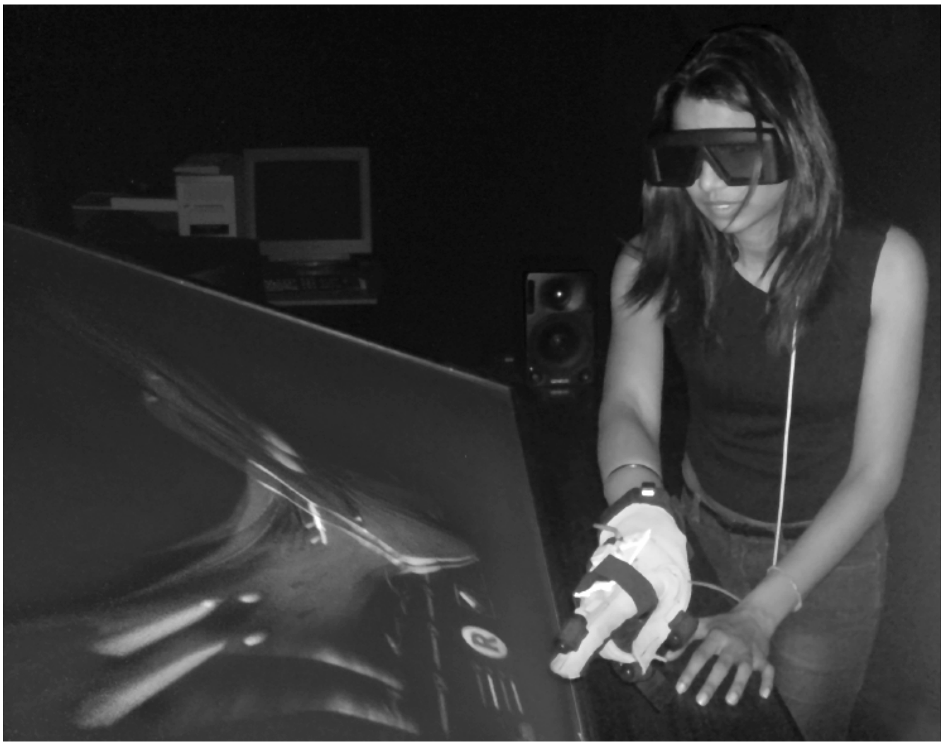

Figure 4: Surgical Trainee during the VR system evaluation.

3. Conclusions

In this paper, we described the design and development considerations of a VR environment specifically designed to integrate with current activity-based tutorials. The results were encouraging and suggest an enhanced synthesis of a spatial anatomical model by augmentation with VR.

However this preliminary inquiry highlighted practical considerations specific to validation for surgical education. This primary evaluation was encouraging but statistically limited by its small subject group. It is our intention to develop further the aforementioned system and improve portability in order to conduct larger studies.

From our experience in performing this study alongside an examination of current literature it seems clear that further work is required to create an empirical evidence base. This combined with the development of practical applications is required in order to bring VR into mainstream surgical education.

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Surgical VR Training Environments:

An Inquiry into the application and validation of Volumetric 3D anatomy tutorials for operative surgical training.

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I. BACKGROUND

An inquiry into the methodology, implementation and evaluation of Virtual Reality (VR) augmented educational tactics applied to operative surgical training. Studies suggest structured VR training shortens the learning curve. Current surgical trainees experience reduced operative exposure exacerbated by depleted undergraduate anatomy teaching. It is hypothesised that surgically focused 3D stereoscopic anatomical models partnered with structured operative curricula could optimize training outcomes from operational exposure.

II. METHODS

We focused on axillary procedures for locally advanced breast neoplasia. We developed a practical methodology for 3D modelling using a specialist surgeon/ anatomist/ 3D modeller team. We modelled a high fidelity 3D representation of the axilla and developed an activity based curriculum. The particular focus was operative anatomy, procedural approaches and applied management principles. A semi-immersive VR interface was designed to facilitate information transfer. This approach was intended as a visual rehearsal and 'schema activator' for use prior to operative sessions. We selected 12 FY2 doctors with a surgical interest and divided them into two arms. We conducted a comparative study of the augmented VR approach and non VR 'traditional' approaches. Both arms were pre-assessed, exposed to the teaching and debriefed using structured MCQs which examined 3D understanding of spatial anatomical relationships and surgical approaches. Subjective user evaluation questionnaires were also completed.

III. RESULTS

The results indicated VR augmentation encouraged engagement, improved understanding of spatial relationships and increased MCQ scores testing spatial understanding and surgical approaches.

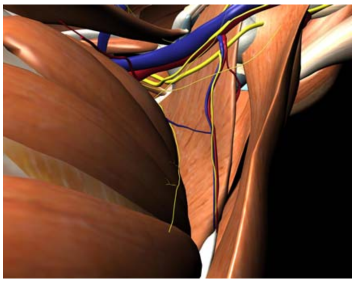
IV. CONCLUSIONS

These initial results are promising and indicate the potential value of further work in this area.

VR	Virtual Reality	FY2	Foundation year two Doctors in training
MCQ	Multiple choice question	3D	Three Dimensional

Surgical Education: A Brief Enquiry into Applied Virtual Anatomy

‘Can Virtual Reality Augment Postgraduate Anatomy Teaching?’



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I. BACKGROUND

This paper presents an inquiry into Virtual Reality (VR) training environments and their application in early postgraduate anatomy teaching. There is great interest in the use of VR applications, but there has been little practical application in the UK. In this inquiry we set out to explore anatomy education and the potential role of VR in the postgraduate setting.

In 1993, the UK General Medical Council published Tomorrow's Doctors leading to a nationwide restructuring of undergraduate medical courses. Traditional courses with distinct pre-clinical and clinical phases gave way to a more integrated approach to undergraduate medical education, with an emphasis on the quality and variety of teaching provided. Universally increased student numbers and internal pressures from a growing undergraduate curriculum resulted in a significant reduction in undergraduate anatomy teaching and reduced student’s exposure to human cadavers[1]. The effect on the anatomical competencies of doctors graduating these new courses has stimulated concerned debate throughout the UK[2].

Now, more than a decade after Tomorrow's Doctors, postgraduate medical training is being transformed. Modernising Medical Careers has created the two-year Foundation Programme, with early selection to streamlined specialist training. The effect of these changes has driven new interest in educational approaches to anatomical training as it becomes a specialist postgraduate subject[3].

The changes in the emphasis from anatomy as an undergraduate to post-graduate discipline may be reflected by the anatomical knowledge of Foundation Year (FY) doctors. The early postgraduate programme is developed in accordance with the Department of Health’s document ‘The Curriculum for the foundation years in postgraduate education and training[4]. Interestingly education in anatomy is mentioned only as an opportunist outcome of experiential learning. In stark contrast the current Part A of the transitional intercollegiate MRCS examination retains an emphasis on applied surgical anatomy[5].

Recent studies have suggested that Virtual Reality (VR) training methods shorten learning curves [6]. Recent research indicates Virtual Reality (VR) interfaces and holographic human body representation could convey appropriate information to the students in an accessibly interactive manner compared with available teaching resources [7]. Contemporary attempts to train medical staff using 3D models were encouragingly positive[8,9].

We developed a detailed 3D model to facilitate current training. The model’s complexity is adjustable to student requirements and easily focused on specific training goals. Additionally, utilizing haptic interaction could improve the user’s spatial awareness of complex structures [10].

This study suggests aimed to answer three main research questions:

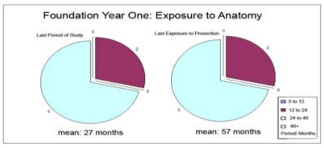
I. What do current Scottish FY doctors think about their anatomical knowledge?
II. What anatomical resources are available to current Scottish FY doctors?
III. Can Volumetric VR augment existing resources available to current FY doctors?

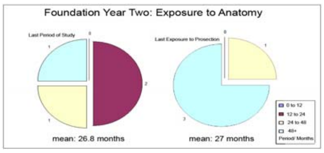
II. METHODS

Informed by current training requirements we designed an anatomically precise model to augment applied anatomy teaching[11]. In turn we developed a VR test-bed specifically for existing problem-based teaching formats. Twelve Scottish FY Doctors, 6 male, 6 female, were selected randomly from a volunteer group. The group represented FY doctor’s with an interest in either radiology or surgery. They completed a structured questionnaire using a nine point Likert scale and a series of open questions. These explored their anatomical training, perceived knowledge, attainment of exams and attitudes and concerns. Internal consistency was confirmed using Cronbach’s alpha. Demographic data was also collected. The group also took part in a semi-immersive VR tutorial and were debriefed by a second questionnaire using a similar mixed method.

III. RESULTS

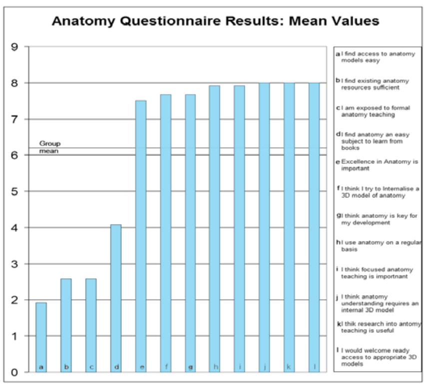
The results reveal concerns that current FY doctors have little recent exposure to anatomical teaching, in particular cadaveric pro-section. For both FY1 and FY2 doctors the mean period since anatomy teaching was 28 months. The mean period since viewing pro-section was 57 months for FY1 and 27 for FY2. This value was explained by the open questions, which revealed that the doctors that had undertaken their collegiate membership examinations (FY1: 15%, FY2: 75%) had arranged private anatomical revision through their graduating university in the preceding 12 months. It is clear that among those who had not arranged teaching, the mean period since exposure to cadveric material in excess of 48 months.





Also clear was that current resources were insufficient for postgraduate demands. The statistical analysis was limited due to the small sample size, however the internal consistency of the results was high (0.81). The results indicated FY doctors were concerned at the lack of accessible anatomical teaching, with questions about access to anatomy teaching and resources scoring the most poorly. In comparison the doctors felt most strongly that anatomy knowledge was central to their professional development, focused anatomy teaching was important and that anatomy required the development of an internal 3D model which was difficult using text books and 2D images.

The debriefing also demonstrated an engagement with VR, the highest scoring questions exploring engagement, understanding of spatial relationships and increased engagement through inter-action. High scoring questions regarding the VR application indicated respondents found it an efficient way to learn and even indicated that it compared favorably with pro-section.



The open questionnaire revealed several themes.

Respondents indicated that they found it difficult to study from 2D images with confidence, as it could lead to mistakes in understanding. Respondents felt that the accessibility of a 3D cadaver via VR was major advantage. Respondents also indicated that the major barrier to learning via VR was the interface, and several indicated that head-tracking and the haptic glove was an unnecessary feature. The open questions also suggested that for tutorials a ‘virtual pointer’ for use by the tutor would be a useful addition and that using a less bulky, higher resolution screen (e.g.: LCD vs. Projection) would be appropriate.

IV. CONCLUSIONS

This enquiry illuminates the educational gap formed between ‘core’ undergraduate anatomy and current postgraduate requirements. It is suggested that current postgraduates find ‘dry’ anatomy resources sub-optimal and human pro-section in the main inaccessible. Interestingly the new generation of doctors find VR anatomy engaging and approachable, but there remains a deficit in the intuitiveness of the human computer interface. There is a lack of empirical research into the educational benefits of volumetric VR in anatomical teaching and learning. This study indicates a place for volumetric virtual anatomy and the continuation of research in this area.

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Augmented Reality Anatomy Training for Inguinal Canal Region

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ABSTRACT

The proliferation of three-dimensional and augmented reality representations offers significant advantages for the accumulation of spatial knowledge regarding human complex structures. Interestingly the interpretation of complex applied medical sciences often requires a strong grasp of the 3D anatomy to which it relates. In practice the obstacle to learning is compounded when procedural techniques and specialist anatomy are effectively taught simultaneously. However it has been shown that learning can be augmented by the use of high resolution 3D models and intuitive human-computer interaction.

In particular this study investigates the structural complexity of the human anatomy with emphasis to the inguinal canal region. Notably this section was highlighted as one of the most difficult for the undergraduate and foundation doctors to mentally visualise and understand. We contrasted the opinions of consultant surgeons and trainee doctors in order to identify the potentials and pitfalls of a VR explanatory model of the inguinal canal in facilitating for surgical anatomical knowledge.

The inguinal canal was of particular interest due to the sequential complexity of the abdominal layers that are exceptionally difficult to comprehend spatially. Therefore we modelled a high fidelity 3D representation of the inguinal canal in anatomical context facilitated by the close collaboration of a multidisciplinary group. This included anatomists, radiologists, laparoscopic surgeons, and human visualisation and interaction experts. In turn we developed an activity-based curriculum, which standardised the augmented teaching and allowed us to evaluate the perceptions of 10 trainee doctors. Feedback from the laparoscopic surgeons was also derived in order to contrast it with the expectations and results of the trainees and their performance using the VR system.

Overall this paper explores the empirical evidence regarding 3D visualisation and the enhancement of spatial learning and describes the integration of robust anatomical modelling techniques, intuitive human-computer interfaces and current educational theory.

Medical Visualisation, Augmented Reality and Anatomy Training: An Intuitive Approach of Visual Arts and Medicine

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ABSTRACT

Medical visualisation has been an active area of research worldwide over the last two decades. Only recently, however, has technology reached a level of maturity and cost/performance ratio that makes its deployment feasible on a large scale. In addition to providing scope to explore research in medical education, this opens a window of opportunity for ground-breaking research and product development that combines the underlying core technology with user-led know-how to deliver the solutions that today's trainees demand.

This paper presents a study into augmented-reality training environments and their application in postgraduate anatomy teaching and medical rehearsal. Interestingly, previous studies suggested that the interpretation of complex medical sciences often requires a strong grasp of the related 3D anatomy. Furthermore there is great interest expressed in the use of 3D applications, yet there has been little strategic application at the national level.
To this end this paper elaborates a multidisciplinary attempt to explore anatomy education and the potential role of augmented reality in the medical sector. Our endeavour has focused primarily on five case studies exploring current approaches augmented with 3D visualisation and prototype human-computer interfaces. Notably the augmented reality and 3D visual representations do not intent to replace the existing teaching methods but to enhance them though a complementary approach. These tools have particular relevance in modern medical training where procedural techniques and specialist anatomy are effectively taught simultaneously in pressured clinical environments.

Overall this paper elaborates the potential merging of various design, engineering and medical disciplines aiming to facilitate human anatomy understanding in training and surgical rehearsal. Early results suggest that the integration of robust anatomical modelling techniques, intuitive human-computer interfaces and current educational theory working synergistically can improve learning outcomes. Finally the paper offers a tentative plan of future work, which will focus in the development of a standardised, reproducible, and robust platform for further training applications.

Abstract - Paper accepted for UK Radiological Congress (UKRC 2008), Birmingham, UK

Enhanced 3D Visualization: Augmenting Musculoskeletal Ultrasound Training

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KEY LEARNING OBJECTIVES

Specialist medical education is changing to reflect current trainee's needs. Detailed anatomy is becoming a post-graduate subject and increasingly doctors must learn anatomy as part of their early specialist training [1]. Interpreting complex 3D subject matter often requires a strong grasp of the 3D anatomy to which it relates. This is compounded when procedural techniques and specialist anatomy are effectively taught simultaneously. However it has been shown that anatomy learning can be augmented by the use of high resolution 3D models [2]. To this end we developed a resource facilitating training in musculoskeletal ultrasound imaging of the foot and ankle. This application had the specific objective of integrating the teaching of specialist 3D anatomy with clinical procedure and image interpretation.

DESCRIPTION

We employed a visualization methodology that allowed real time interlinking between a low latency rotational 3D anatomical model, visual descriptors of ultrasound technique (positioning, movement, field) and clinical ultrasound images. Notably the system was designed to synchronously augment current clinical training or to be self-led and asynchronous. It was designed to convey the anatomy to a multi-disciplinary audience. The approach capitalises on current educational theory and enhances the current approaches by utilising advanced visualisation with an emphasis on practical and intuitive interfaces [3].

CONCLUSION

This paper explores the empirical evidence regarding 3D visualisation and the enhancement of spatial learning and describes the integration of robust anatomical modelling techniques, intuitive human computer interface and current educational theory. [4].

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Abstract - Paper accepted for UK Radiological Congress (UKRC 2008), Birmingham, UK

International Conference of Medicine Meets Virtual Reality 16th, Long Beach, California, USA. / in Stud Health Technol Inform (2008)

Abstract - Paper accepted for UK Radiological Congress (UKRC 2008), Birmingham, UK

Interpreting Lung Collapse:

A randomised controlled study into the impact of three-dimensional animation

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[2]Ayr Hospital
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[3]University of Glasgow / Glasgow School of Art
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PURPOSE

The use of computer-generated anatomical models has become widespread in anatomy teaching. Several randomized controlled studies have shown positive learning outcomes in basic undergraduate anatomy. Recent studies have suggested Virtual Reality has a role in shortening the learning curve in postgraduate medical training. Correct interpretation of radiological images often relies upon a three dimensional (3D) internal understanding of anatomy, but little is know about the potential role of enhanced visualization in radiological training. To this end we have designed a randomized controlled study exploring trainee's radiological interpretation of lung collapse, anatomical knowledge and visual-spatial ability.

MATERIALS/ METHODS

We designed a 3D animation series demonstrating the range of lobar collapse. In addition we developed an integrated computer-based educational package bringing together plain film, CT data and traditional schematic diagrams. 20 current radiology trainees at a deanery study day will be randomized into two equal groups, one tutorial group given additional access to the 3D animation resource. Both arms are timed, pre-assessed for knowledge, prior experience, visual-spatial skills and then debriefed by identical MCQ and qualitative survey instruments integrated with the educational package.

RESULTS/ DISCUSSION

The results will be collected (using Questionmark-Perception) and the mean scores compared with a 2-tailed Student's t-test (SPSS). We will use similar methods to analyse the visual-spatial data and in addition utilise chi-squared tests to ensure the groups are comparable. The qualitative analysis includes a Likert questionnaire analyzed for internal consistency (Cronbach's alpha) and thematic analysis of several open questions. The results are explored in relation to recent publications and the scope for further investment in terms of education provision and research.

Literature Review

Medical visualisation today is a vast field of active research and development. The following state of the art review identifies the relevant key players and how the Scottish Medical Visualisation Network expands upon their previous work. The identified key areas include advanced visualisation, simulation and e-education.

Advanced Visualisation

The field of advanced medical visualisation is concerned with creating imagery from raw medical data. Research ranges from the extraction of features from sensor data (e.g. volume visualisation of scans) to novel rendering algorithms for complex three-dimensional data sets. Various research groups focus on advanced visualisation, most of them coming from a computer science and visualisation or signal processing background.

Previous studies strongly suggested that teaching anatomy and surgical rehearsal can be significantly improved using advanced visualisation technologies (Pandey and Zimitat, 2007). Furthermore, the combination with appropriate haptic interaction enables the user to interact freely with a volumetric 3D model, selecting their own number of infinite viewpoints, a factor suggested to be central to spatial anatomical understanding (Nicolson and Chalk, 2006). In addition the importance of facilitating a balanced learning approach including visualisation skills and spatial awareness has been highlighted (Pandey and Zimitat, 2007; Garg et. al. 2001).

Yaoping Hu et. al., (2005), from University of Calgary, Canada, observed that 3D displays of lung cavities are feasible and have distinctive advantages over two-dimensional views by decreasing the workload by about 50%, reducing planning time by about 30%, and increasing the accuracy of predicted re-sectionability by about 20%. These results clearly advocate benefits for employing 3D displays in surgical treatment of lung cancer. To this end, TU Delft has focused on developing new techniques for pre-operative planning and intra-operative guidance, clinical diagnosis and medical research (Blaas et. al. 2007).

Simulation

Surgical simulation typically follows the visualisation process and is currently a very active research area. The field extends upon visualisation by introducing behavioural simulation into the previously static data sets.

Exceptional studies and projects are under development in several departments such as CAVI (Center for Advanced Visualisation and Interaction), University of Aarhus, Denmark with special interest in VR simulation of difficult surgical operations (Sørensen et. al., 2003; Mosegard and Sørensen, 2005). This research group seeks to present a virtual environment where surgeons can train surgical procedures. Their research has focused on the development of faster calculation of deformation and visualisation, with emphasis to simulate very complex morphology in real-time.

A step further is the joint research of the MIT Artificial Intelligence lab, and Surgical Planning Laboratory of Brigham and Women's Hospital which produced a series of projects aiming to enhance reality visualisation of internal anatomical structures overlaid on live video imagery of patients; hence allowing simulation and navigation by the surgeon in virtual surgical rehearsal in real time (MIT, 2005).

Although this might be a future target to achieve for the Scottish Medical Visualisation Network, it still stands as a strong indication of the contemporary and future trends and needs. Finally such partnerships between academic institutions and medical facilities can be achieved solely by close collaborations between multidisciplinary groups.

e-Education

The method of e-Education has lately been adapted by universities across the world as it offers time-flexible training, effortless repetition of tutorials and minimises the space constrains of a classroom (Brenton et. al., 2007). A direct application is the Primal Picture website which is probably the most detailed database for human anatomy teaching. The visualisation of their anatomy examples is derived primarily from CT and MRI scans which were further used to produce highly detailed anatomical structures.

These visual cues are complemented by a succinct document which describes the anatomical details, position and pathology of each section of the human body. However the complexity of the 3D models can often be quite difficult for a student to perceive and accumulate. Furthermore the manipulation of the 3D data is based on a single rotation pattern which does not allow the user to investigate complex structures from multiple points of view.

Similarly ContMedia has developed a human anatomy DVD which includes teaching material in the forms of human anatomy, physiology, anatomy atlas and medical dictionary. However the majority of these products lack intuitive interfaces and visualisation quality, although they can serve the purpose of an introductory course in anatomy.

Typical book-related anatomy material offered a digital format leaning towards an e-Education model which could be physically smaller to store and handle. In particular, Gray's Anatomy 39th edition offers a medical images database which correlates directly with the book's documents and printed images. Still, the images are based in 2D representations, photos or depictions of anatomical structures and do not reflect the spatial relation of the real three dimensional body members.

Towards this educational approach Harvard University Medical School developed the Human Systems Explorer, which is effectively a web-based application that investigates through 2D visualisation complex human anatomy and pathology issues. This software acts as an interactive teaching tool designed to clarify difficult concepts in pathophysiology and examines how the new technology can be used effectively to aid students in the classroom and beyond (Harvard, 2007).

The Scottish Model

Medical Visualisation is an inherently interdisciplinary field. Most initiatives therefore include a range of expertise, typically including medical research or teaching, imaging and sensor technology, computer graphics and visualisation, and human-computer interaction. Most of the networks are research-driven, aimed at generating new technologies and knowledge. The Scottish Medical Visualisation Network takes a different approach in that it is application-driven, aiming to bring visualisation technology into the field.

The Scottish collaboration of different disciplines presented a plethora of case studies that were varying in importance and complexity for each medical specialty. Due to time and cost limitations, five case studies were selected for an initial stage development. The material produced has since been directly transferred into medical lectures with encouraging response from the medical students.

The prototype interfaces developed for the case studies and the advanced visualisation techniques were tested in comparative studies between different Foundation Year Doctors' (FYs) groups. The methodologies employed and the results were peered reviewed and presented in six International and British conferences, providing further proof of the effectiveness of this application-orientated technology.

The Scottish Medical Visualisation Network therefore has a role to play in advanced visualisation surgical simulation and e-education research. The Network is unique in that it is user and applications led giving Scotland an advantage in the international field and the potential to be a world leader in medical visualisation.

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First Workshop - 29th May 2007

Workshop Invitation

Agenda

Welcome - Professor Paul Anderson, Director, Digital Design Studio, Glasgow School of Art

Anatomy Reconsttucted - Professor Ian Parkin, Ninewells Hospital, Dundee

Surgical Rehearsal - Mr Bill McKerrow, Consultant ENT Surgeon, Raigmore Hospital, Inverness

Medical Visualisation - Dr. John Reid, Consultant Radiologist, Borders Genral Hospital, Melrose

Visualisation for Medical Education - Dr Ben Ward, The Royal College of Surgeons of Edinburgh

MEDICAL VISUALISATION WORKSHOP

29th May 2007

"Bringing together academics, clinicians, practitioners, scientists and medical and technical visualisation specialists"

About the workshop:

Contemporary advances in medical 3D visualisation are enabling medical practitioners to view and interact with human body without the need or reliance on the use of physical body.

This workshop is intended to spark debate and reflection on the needs and issues stemming from medical education and surgical rehearsal and explore how visualisation technology can be used to support present and future medical staff.

Who should attend:

Medical practitioners, medical educators, bioengineers, researchers from an academic or clinical background, visualisation experts.

Location:

Digital Design Studio,
House for an Art Lover,
Bellahouston Park,
10 Dumbreck Road
Glasgow, Scotland,
G41 5BW

Workshop Coordinator
Vassilis Charissis
Tel: 0141 353 4616
Email: v.charissis@gsa.ac.uk

DIGITAL DESIGN STUDIO THE GLASGOW SCHOOL OF ART

Scottish Funding Council

MEDICAL VISUALISATION WORKSHOP

PROGRAMME 29th May 2007

- 10.30-10.45 Welcome Coffee & Tea

- 10.45-12.15 Presentations

Introduction
Prof. Paul Anderson Director of Digital Design Studio

Contemporary Anatomy Issues
Prof. Ian Parkin, chair of Applied Clinical Anatomy, University of Dundee

Surgical Rehearsal
William McKerrow, Consultant ENT Surgeon, Raigmore Hospital Inverness

Medical Visualisation
Reid, John H DMRD FRCR, Consultant Radiologist, Department of Radiology
Borders General Hospital

Educational Medical Visualisation
Ben M. Ward, Royal College of Surgeons of Edinburgh

- 12.15-13.00 Lunch Break

- 13.00-13.45 Medical Visualisation Demonstrations

Large projection Area – Hydra room

Virtual Reality Facility and Haptic Interaction – AutoEval

Virtual Reality Facility and Investigation of human organs - Sci-Fi

- 13:45-15:45 Discussion session

Potential Case Studies

Collaborations & Funding Opportunities

Planning for future

- 15:45 –16:00 Conclusions

DIGITAL DESIGN STUDIO THE GLASGOW SCHOOL OF ART

Scottish Funding Council

Programme

10:30 – 10:45 Welcome Coffee & Tea

10:45 – 12:15 Presentations

Introduction
Prof Paul Anderson, Director of Digital Design Studio

Contemporary Anatomy Issues
Prof Ian Parkin, Chair of Applied Clinical Anatomy, University of Dundee

Surgical Rehearsal
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Educational Medical Visualisation
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12:15 – 13:00 Lunch break

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Large Projection Area – Hydra room

Virtual Reality Facility and Haptic Interaction – AutoEval

Virtual Reality Facility and Investigation of Human Organs - SciFi

13:45 – 15:45 Discussion Session

Potential Case Studies

Collaboration & Funding Opportunities

Planning for the Future

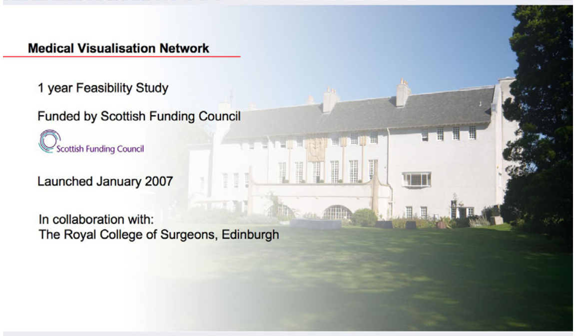
15:45 – 16:00 Conclusions

DIGITAL DESIGN STUDIO THE GLASGOW SCHOOL OF ART

Scottish Funding Council
Promoting further and higher education

Welcome

Prof. Paul Anderson
Director of Digital Design Studio



Medical Visualisation Network

1 year Feasibility Study

Funded by Scottish Funding Council

Launched January 2007

In collaboration with:
The Royal College of Surgeons, Edinburgh

Aims – of the Network

Aims

To establish a network of academics, clinicians, practitioners, medical and technical visualisation specialists, to identify areas where real-time 3D digital visualisation technologies can support medical education and training.

- Augment and supplement cadaver-based practice.
- 3D visualisation supporting patient understanding and recovery, and the promotion of good health and well-being.
- To enhance contemporary and future clinical diagnosis and surgical rehearsal.

There is a list of current network members and attendees in your pack.

Introduction **Network** Research Medical Future

Aims – of the Workshop

Aims for today:

- To begin to establish a strategic 'connected' network in Scotland
- Receive a range of scoping presentations from a range of disciplines
- To experience a range of visualisation and interaction technologies that supports medical visualisation
- To discuss establishing a small number of case studies (supporting RDG proposal)
- To discuss further collaboration and funding opportunities
- Planning for the future – workshops and website

Introduction **Network** Research Medical Future

Timetable – of the Workshop

Timetable

10.45-12.15 Presentations

12.15-13.00 Lunch

13.00-14.00 Medical Visualisation Demonstrations

14.00-14.15 Coffee

14.15-15.45 Discussion Session

15.45-16.00 Conclusions

Introduction **Network** Research Medical Future

Introduction – to DDS

DDS

Digital Design Studio (DDS), established 1997

A postgraduate research and commercial centre, specialising in advanced 3D visualisation and human/computer interaction technologies

Education

Visualisation and interaction research

Commercialisation and consultancy

Introduction Network **Research** Medical Future

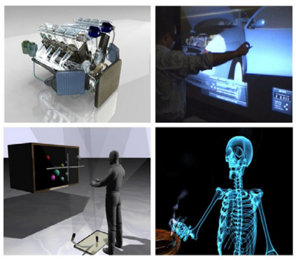
Introduction – to DDS

The DDS provides:

- Information visualisation
- Product and urban visualisation
- Human-Computer Interaction (HCI)
- Technology integration
- Interactive internet applications

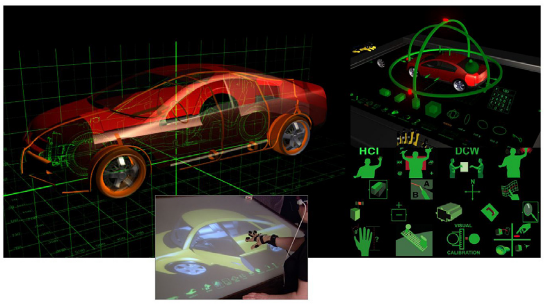
Core skills:

- 3D real-time visualisation,
- Digital modelling and animation
- Advanced projection systems
- Haptic devices
- Spatialised sound
- Gesture recognition & machine vision
- Speech recognition

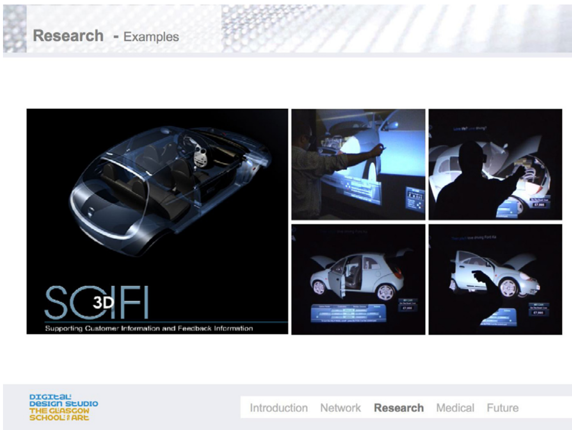


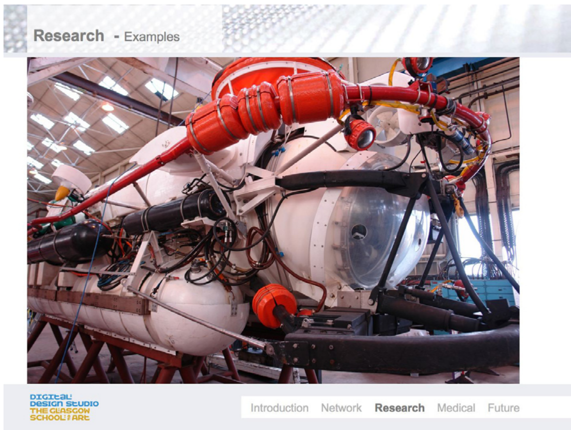
Introduction Network **Research** Medical Future

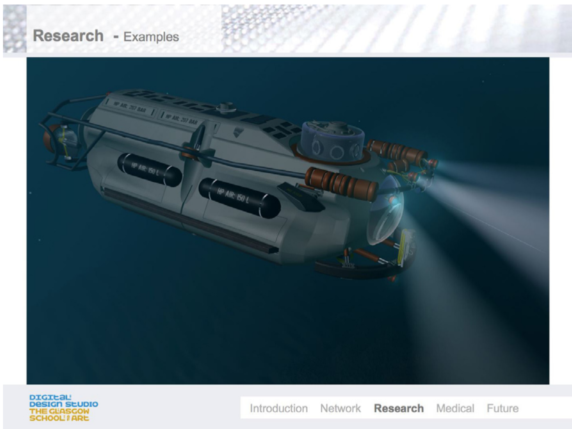
Research - Examples



Introduction Network **Research** Medical Future


Research - Examples
SCiFI 3D
Supporting Customer Information and Feedback Information
Introduction Network Research Medical Future


Research - Examples
Introduction Network Research Medical Future


Research - Examples
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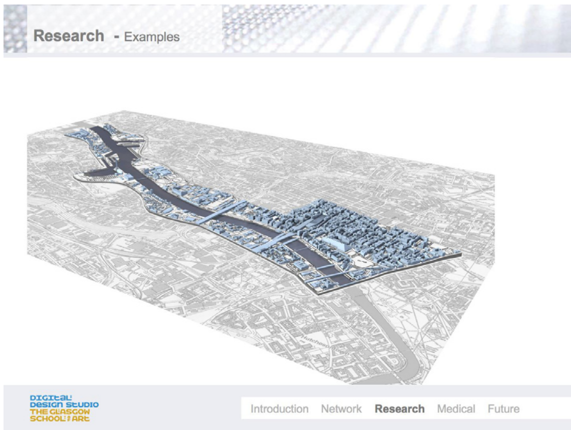
Research - Examples
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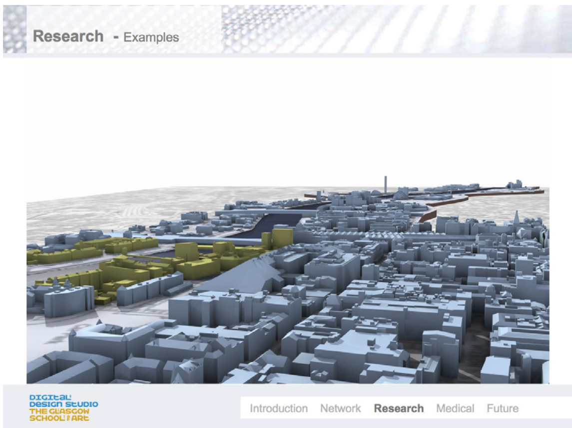
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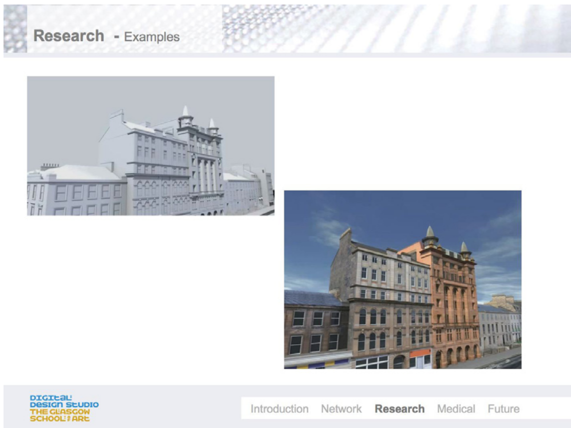
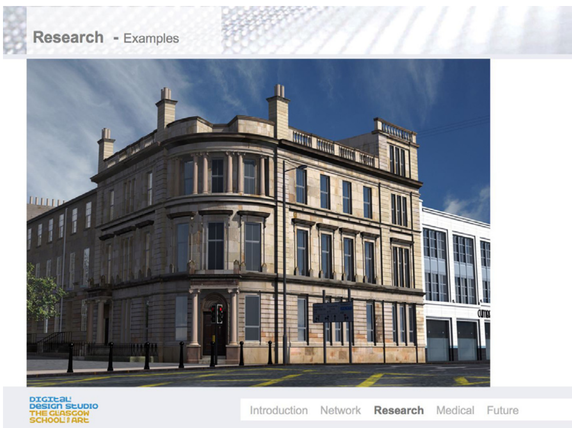
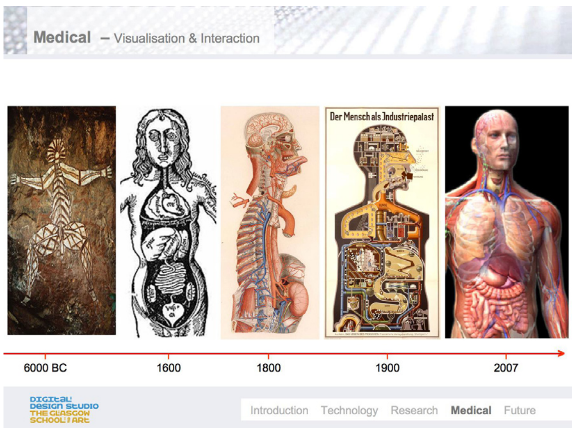
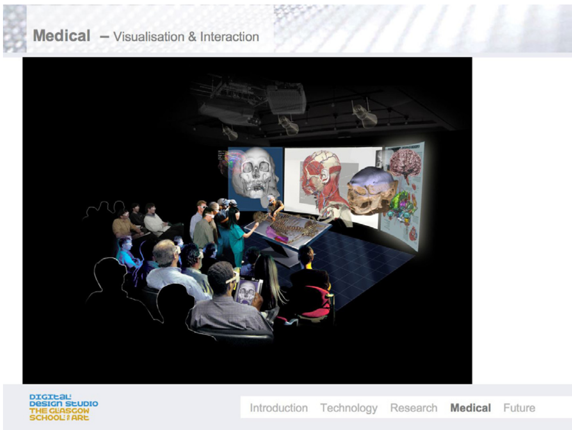
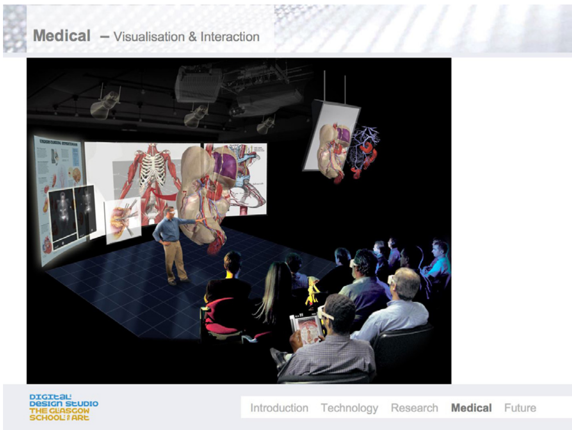
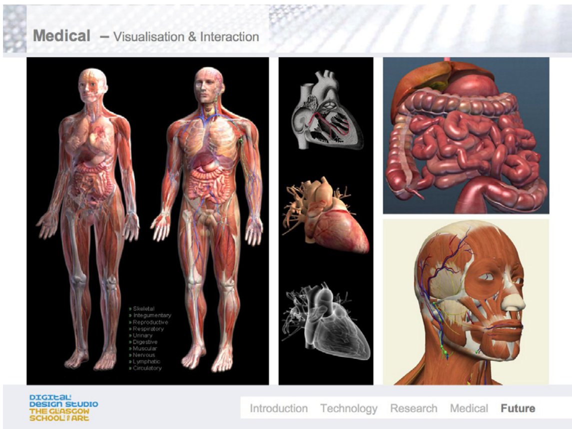

Research - Examples
Introduction Network Research Medical Future

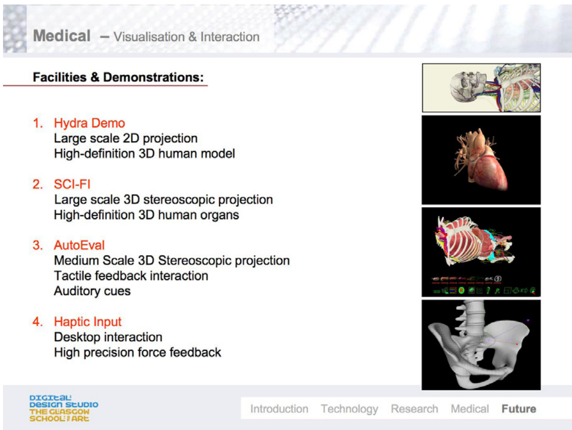

Research - Examples
Introduction Network Research Medical Future

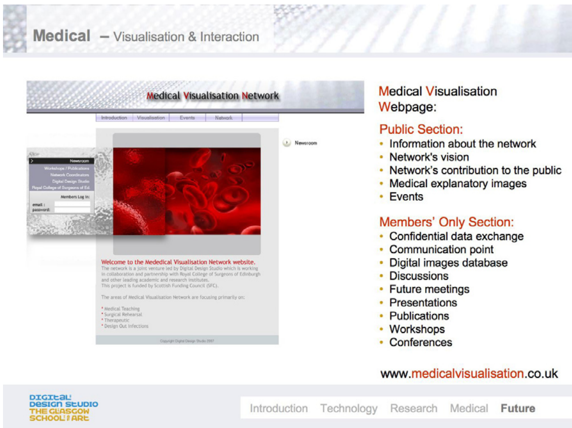

Medical – Visualisation & Interaction
Der Mensch als Industriepalast
6000 BC
1600
1800
1900
2007
Introduction Technology Research Medical Future


Medical – Visualisation & Interaction
Introduction Technology Research Medical Future


Medical – Visualisation & Interaction
Introduction Technology Research Medical Future


Medical – Visualisation & Interaction
Introduction Technology Research Medical Future


Medical – Visualisation & Interaction
Facilities & Demonstrations:
1. Hydra Demo
Large scale 2D projection
High-definition 3D human model
2. SCI-FI
Large scale 3D stereoscopic projection
High-definition 3D human organs
3. AutoEval
Medium Scale 3D Stereoscopic projection
Tactile feedback interaction
Auditory cues
4. Haptic Input
Desktop interaction
High precision force feedback
Introduction Technology Research Medical Future


Medical – Visualisation & Interaction
Medical Visualisation Network
Medical Visualisation Webpage:
Public Section:
• Information about the network
• Network's vision
• Network's contribution to the public
• Medical explanatory images
• Events
Members' Only Section:
• Confidential data exchange
• Communication point
• Digital images database
• Discussions
• Future meetings
• Presentations
• Publications
• Workshops
• Conferences
www.medicalvisualisation.co.uk
Introduction Technology Research Medical Future

Anatomy Reconstructed

Anatomy

How it all fits together

How it all works

Anatomy Reconstructed

Anatomy

How it all fits together

How it all works

What could be easier?

Cadaver

3-D

Active learning

(dissection/pro-section)

Position and relationships for examination, surgical approach and tumour spread

But if the cadaver is not available:

Reconstruct to offer the same 3-D, active, spatial learning

Joints: movement

(heart, lungs, intestine, blood flow, nerve conduction)

Procedures

Joints: movement

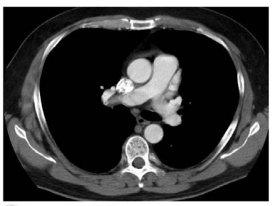
(heart, lungs, intestine, blood flow, nerve conduction)

Procedures

Simulate:

Function, movement

Clinical procedure or surgical approach



Sectional Anatomy

Relate cadaver to clinical investigation

i.e. add "life"

Keep abreast of advancing diagnostic technology

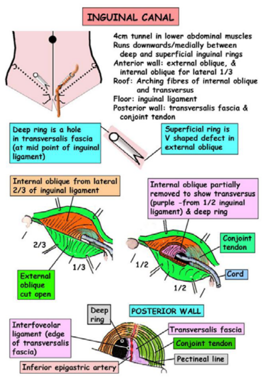
(digital reconstruction is here)

Difficult Concepts:

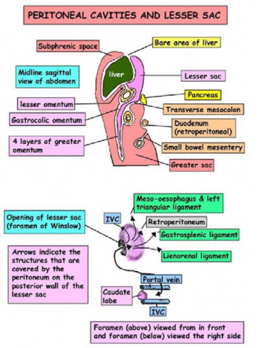
Impossible (almost) with embalmed cadavers

Inguinal canal

Hernias



Lesser sac



Anatomy: Digital Design Workshop May 07

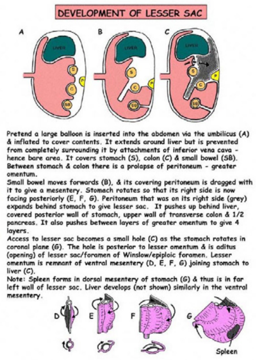
Think in 3-D

Moving

Translation from embryology to adult

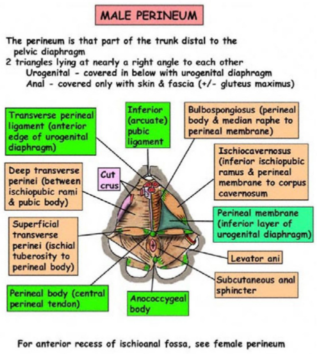
Potential spaces

(are exactly that, but clinically important)



Anatomy: Digital Design Workshop May 07

Perineum

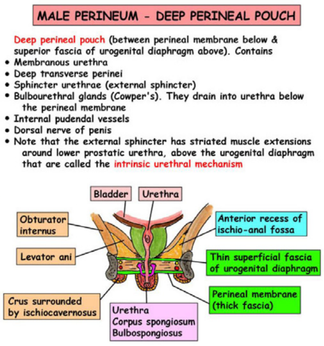


Anatomy: Digital Design Workshop May 07

Perineum

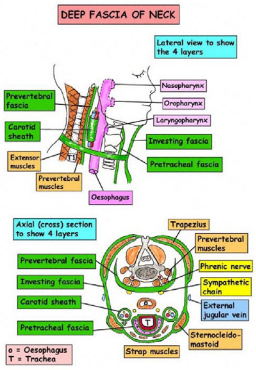
View from different angles to understand

Alteration with posture, age and clinical condition



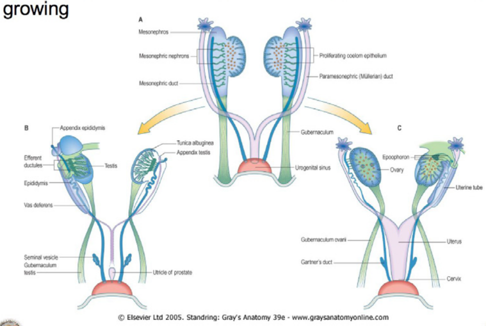
Anatomy: Digital Design Workshop May 07

Fascia and fascial spaces of neck and thorax



Anatomy: Digital Design Workshop May 07

Embryological 3-D development, moving and differentially growing



Anatomy: Digital Design Workshop May 07

Anatomy Reconstructed

•Reconstruct to offer the same 3-D, active, spatial learning

•Simulate: function, movement; clinical procedure or surgical approach

•Add "life" and keep abreast of technology

•Difficult concepts: not visible on cadaver; 3-D; moving with development, posture and age

•Inguinal region; peritoneum and lesser sac; perineum; potential spaces

•Embryology (similar issues): watch A become B or C

Anatomy: Digital Design Workshop May 07

Anatomy Reconstructed

Add insight and understanding to promote learning, and safe clinical practice

Illustrations courtesy of: University of Dundee; University of Cambridge; R.H. Whitaker; Gray's Anatomy, Elsevier

Thank you

Anatomy: Digital Design Workshop May 07

Surgical Rehearsal

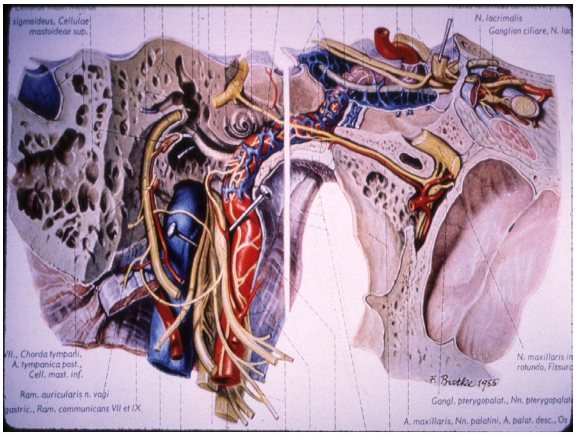
Bill McKerrow
Consultant ENT Surgeon
Raigmore Hospital, Inverness

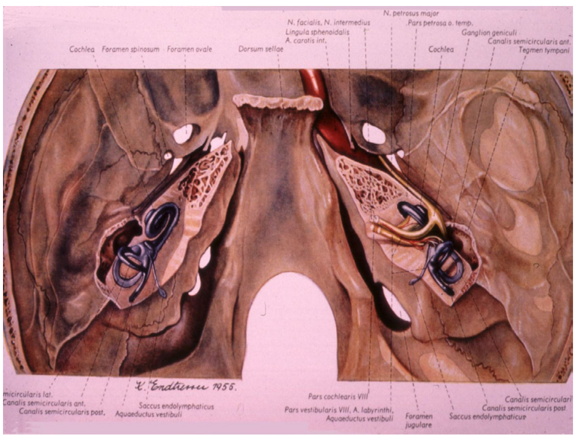
Some Challenges in Delivery of High Quality Surgery

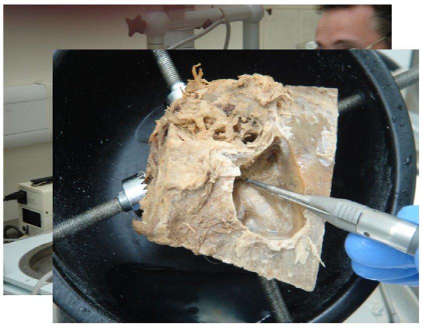
Training
Refreshing
Skills Maintenance
Skills Development

Current Practice

Learn Anatomy
Learn steps of operation
Watch
Assist
Progressively do parts of procedure
Do all procedure
Achieve competency in all circumstances





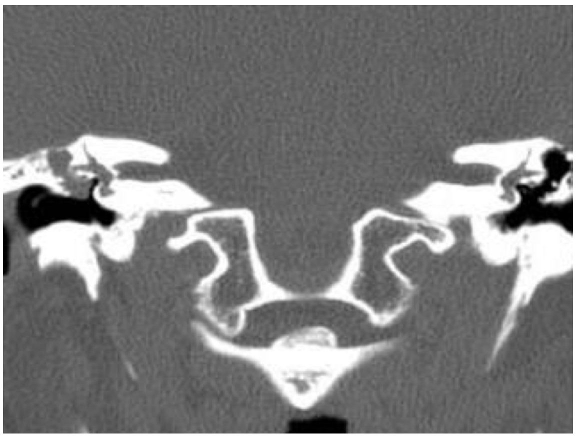


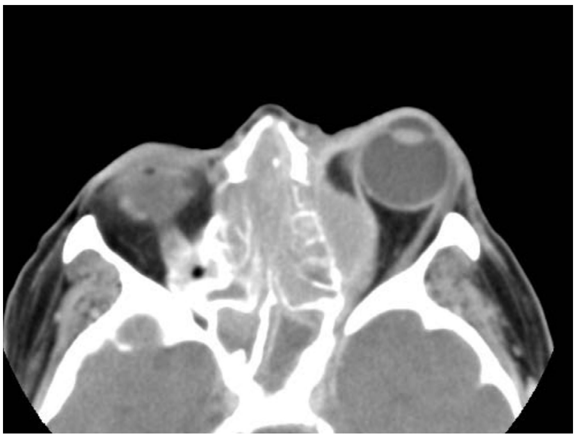
A New Dimension

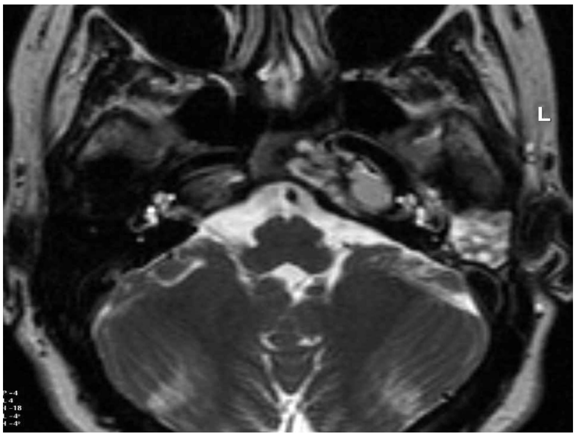
How can we practice for real operations?
Different anatomy
Different pathology
Different hazards

Imaging

Ultrasound
CT
MRI

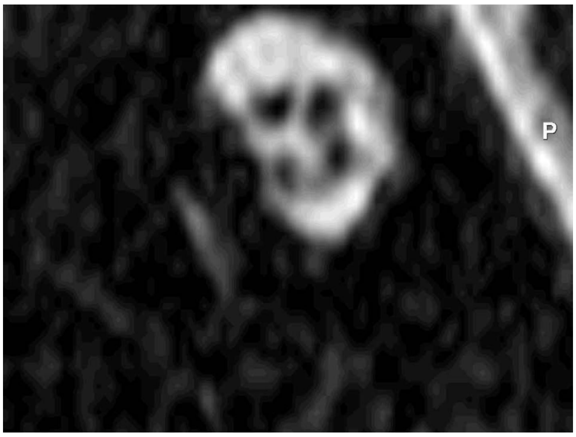






The Concept

To transfer individual patient clinical anatomical and pathological data (photographic and imaging) into a three dimensional virtual reality format.



The Goal

Rehearsal of the surgical procedure for the individual patient

Medical visualisation workshop

29th May
John Reid
Melrose

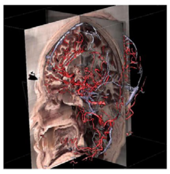
Our core business:

- What's wrong with the patient?
- What can you do for the problem
- What is the prognosis

Radiology

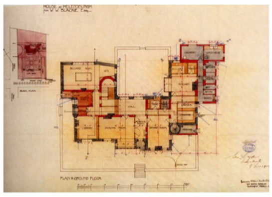
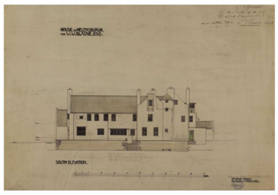
- Anatomy:

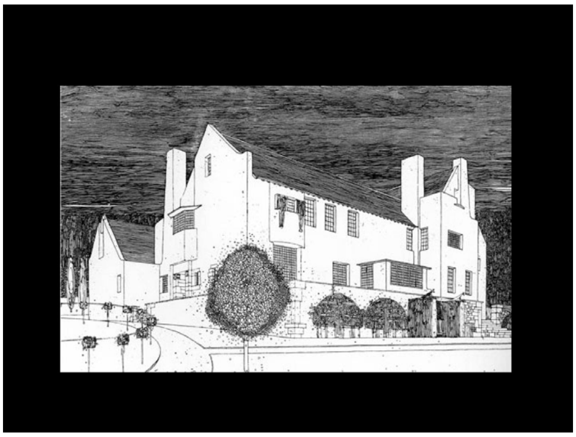




Radiologist cf architect

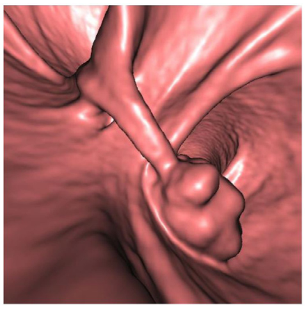
- We use 1 or 2 dimensions

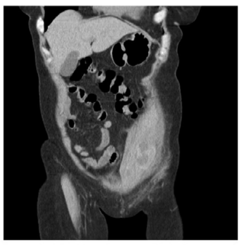


Multiplanar reformats


Transmission of information



Treatment planning / monitoring

3D imaging

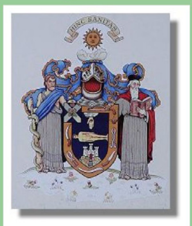
- Multiplanar reformats as routine
- 3 D colonography
- 3 D bronchoscopy
- 3 D nuclear medicine

- 3 D information transmission

3D imaging

- Multislice CT / MRI
- Multiplanar pathology datasets
  - Teaching
  - Reporting
  - Treatment planning

Visualisation for Medical Education 'Putting it all in Context'



Mr Ben Ward
Surgical Fellow (UOE)
RCSed (ESSQ)

What are the current Challenges? How can we help each other meet them?

- Medical Education in 2007
- Osmosis and Survival?
- Facing the Net Generation
- Medicine's never a game, is it?

Challenges in Medical Education 2007

- Why is Medical Education so important?

- Traditional Training vs MMC,
- Shifting Focus on undergraduate curricula,
- Shorter more focused postgraduate training,
- Continued Learning through-out a career,
- Emphasis on Revalidation/ CPD

Osmosis and Survival?
Educational needs for modern Medicine

- Changing Undergraduate Curriculum/ Staffing levels in Anatomy Teaching
- Postgraduate effects of the new undergraduate curriculum
- Sophisticated learners/ Sophisticated subject
- Facing the Net Generation (NetGeners)
- From Undergraduate to CCST and beyond
- Increasing requirement for flexibility; distance learning; eLearning
- The development and practical evaluation of Web3D Technology

- **There is a pressing need for robust evaluation of new methods including publication of real world development experiences.**
  H. Brenton et al. / Computers & Education 49 (2007) 32–53

Facing The Net Generation
Our New Generation of Doctors

- A new population of learners with unique characteristics
- 7% of the population today (Bartlett 2005)
- Very education oriented. (Whitney-Vernon 2004)
- NetGeners learn differently from their predecessors
- Not only are NetGeners acculturated to the use of technology, they are saturated with it.
- Oblinger and Oblinger 2005; Prensky 2006; Tapscott 1998

By the age of 21 the average NetGener will have spent….

- 10,000 hours playing video games,
- 200,000 e-mails,
- 20,000 hours watching TV,
- 10,000 hours on cell phones,

  Oblinger and Oblinger 2005; Prensky 2006; Tapscott 1998

- under 5,000 hours reading

  (Bonamici et al. 2005).

Digital Natives
10 Years of the Net Generation

- Having been raised in an age of media saturation and convenient access to digital technologies, NetGeners have distinctive ways of thinking, communicating, and learning.

- (Oblinger and Oblinger 2005; Prensky 2006; Tapscott 1998).

Medicine isn't a Game, or is it?

- Computer games have made a significant cultural, social, economic, political, and technological impact on society

  (Newman 2004),
- Given the widespread popularity of video games, their ability to sustain long-term player engagement with challenging tasks its no wonder they interest educationalists.

  (Gee 2003),
- Gaming is interesting in its tendency to elicit proactive player communities

  (Rheingold 1994),

Game-Informed Learning:
Applying Computer Game Processes to Higher Education M.Begg, D.Dewhurst, and H.Macleod

Game-informed Learning

- Developed from the same principles as constructivist pedagogy and PBL.
- **The educational processes themselves should be informed by the experience of game-play.**
- Students invited to perform as medical investigators
- Students compelled to intervene in a simulated environment where each intervention creates consequences that prompt further action.
- Interaction with a rich, involving, stimulating, interactive contextualised environment promotes an enriched engagement with the subject domain.
- The provision of 'thickly authentic' settings. (Shaffer and Resnick 1999).

Game informed learning at RCSed

budding surgeons make the cut

The College is hosting a Surgical Skills competition to involve school children in the Quincentenary celebrations, writes *Andrew de Beaux*

A pilot day in November 2002 assured all involved that the Surgical Skills School

primary aim of the competition was to engage pupils in the Quincentenary celebrations, the secondary aim to

with a tour of the museum. After lunch it was back to the skills lab to get plastered – quite literally. Both members of the team applied a forearm POP to each other – not at the same time of course! The day finished with a key-hole surgery session. Stacking sugar lumps, then cutting a circle out of a glove increased the competition between the teams. Indeed, the enthusiasm and technical skills of the school kids have been very impressive.

Teams from Aberdeen Grammar, Albyn School for Girls, Balwearie High, Boclair Academy, Dollar Academy, Dumfries Academy, Grange Academy, Keith Grammar, Kelso High, Kenmay Academy, Knox Academy, Lanark Grammar, Linlithgow Academy, Lochgilphead High, Millburn Academy, Morrisons Academy, Peterhead Academy and St Thomas of Aquinas High School are through to the two semi-finals.

Finger on the **Pulse!!**
What the American's are doing.

- Funded by the US Office of Naval Research
- Designed by developer 'BreakAway', Hunt Valley (Md.)
- $7.5 million project for Nursing, Medical training.
- Proof-of-concept prototype finished by the end of 2006.

PULSE!!

Clinical Gaming and Learning

- Any domain of knowledge, academic or not, is first and foremost a set of activities and experiences.

  Physicists *do* physics. They *talk* physics. And when they are being physicists, they *see* and *value* the world in a different way than do non-physicists.

- When learners use real tools and methods to address issues they care about motivation and learning tend to follow.
- When one treats knowledge first and foremost as activity and experience, not as facts and information **the facts come to life.**

Meeting the challenges together.

- Allows rehearsal of clinical decision making in a rich, authentic, safe, ?remote, plastic, environment.
- Visualisation extends the scope of subject domains.
- Game-informed learning; face to face, augmented reality, online.
- 3D visualisation for 3D 360° immersion.
- 'Thickly Authentic' settings suit NetGener learners.
- Enhanced engagement promotes critical mass for eLearning communities.
- An exciting and expanding area of educational research
- The for Scotland to gain an expert community in a globally relevant field.

If your Browsing........

- http://www.educationarcade.org
- http://www.gamesforhealth.org
- http://www.socialimpactgames.com

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Second workshop - 14th November 2007

Agenda

Sometimes - what you see is not what you 'get' - Professor David Rowley, Director of Education, The Royal College of Surgeons of Edinburgh

Welcome - Professor Paul Anderson, Director, Digital Design Studio, Glasgow School of Art

Medical Educational Research: Health though Innovation - Dr Ben Ward, The Royal College of Surgeons of Edinburgh

Anatomy Reconstructed - Professor Ian Parkin, Ninewells Hospital, Dundee

Speaker Profiles

Partner Profiles

Certificate of Attendance

14 November 2007

Agenda

Chair: Prof. Paul Anderson

09:15 Registration (coffee and tea)

09:45 Welcome by John Orr, President of the Royal College of Surgeons, Edinburgh

09:50 Professor David Rowley, Director of Education, Royal College of Surgeons, Edinburgh

10:00 Professor Paul Anderson, Digital Design Studio, Glasgow School of Art

10:10 Improved rendering of 3D images to augment applied anatomy teaching Presentation by Dr Ben Ward, Royal College of Surgeons, Edinburgh and Lucy Whittaker, Edinburgh University

10:30 Procedural rehearsal of a virtual lumber puncture with haptic (feeling) feedback. Presentation by Dr David Chanock & Dr Jillian Hewitt-Gray, Ayr Hospital

10:50 A 3D animation of the anatomy of the ankle and foot for ultrasonography training. Presentation by Dr David Chanock and Mr Anand Rattansingh, Ayr Hospital

11:10 The development of 3D modelling for undergraduate teaching (inguinal canal). Presentation by Professor Ian Parkin, Ninewells Hospital, Dundee

11:30 The use of 3D animation to visualise structures from 2D plain films of the chest. Presentation by Dr David Chanock, Ayr Hospital

11:50 Q&A session

12:30 Lunch and Networking

13:30 Open Space – circuit of demonstrations including:

- Phantom arm haptic Lumbar puncture
- Approaches to VR research – the 3D heart
- Real-time VR anatomy - demonstration of the virtual human body
- A semi-immersive VR interface with 3D visualisation, 3D sound and haptic demonstration of a virtual human body

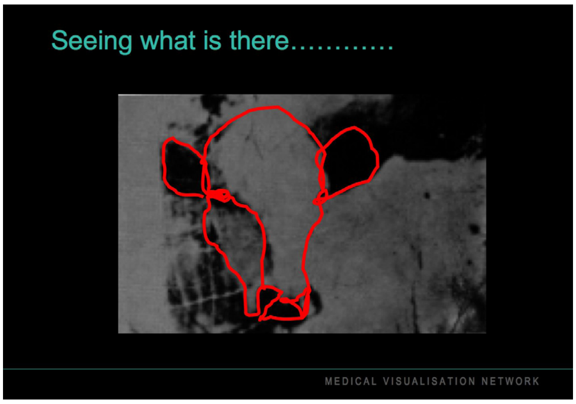
15:00 Plenary session

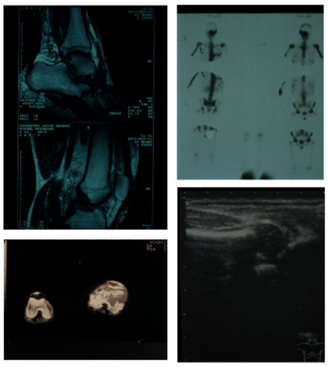
15:30 Close

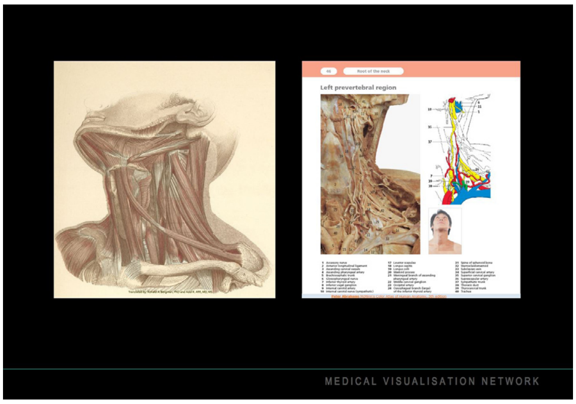
Digital Design Studio ■ Royal College of Surgeons

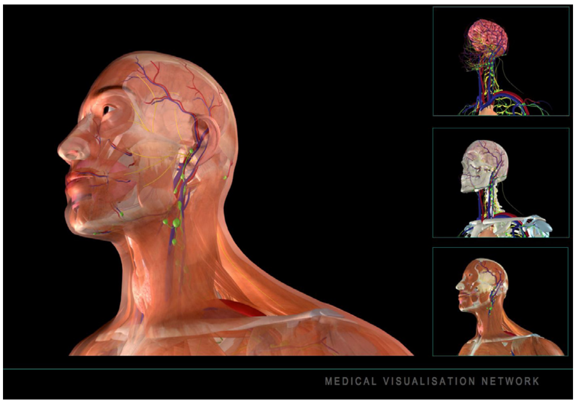

MEDICAL VISUALISATION NETWORK
second workshop
Sometimes – what you see is not what you "get"
Professor David I Rowley
Director of Education at the Royal College of Surgeons of Edinburgh
Professor of Trauma and Orthopaedic Surgery, Dundee University
Visiting Professor of Surgical Education, Edinburgh University
Digital Design Studio
The Glasgow School of Art
The Royal College of Surgeons
Scottish Funding Council


What do you see?
MEDICAL VISUALISATION NETWORK


Seeing what is there…………
MEDICAL VISUALISATION NETWORK

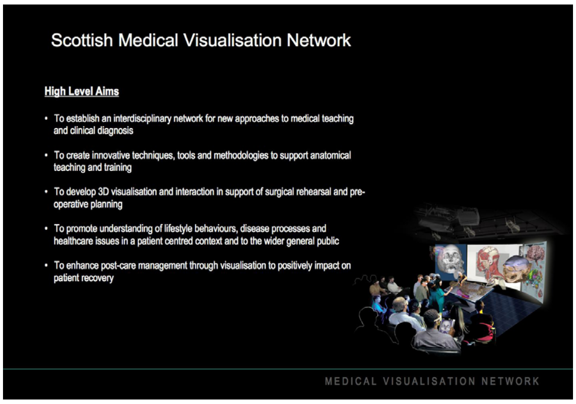


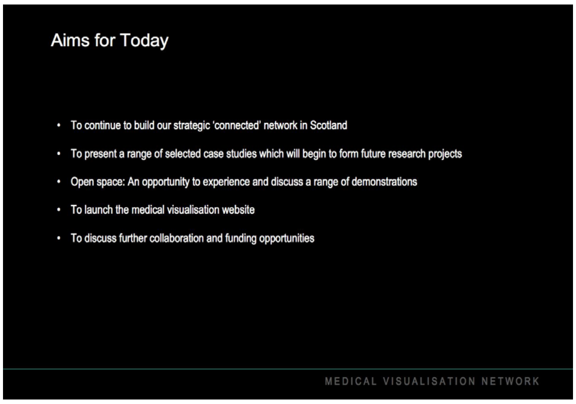

Left prevertebral region
MEDICAL VISUALISATION NETWORK

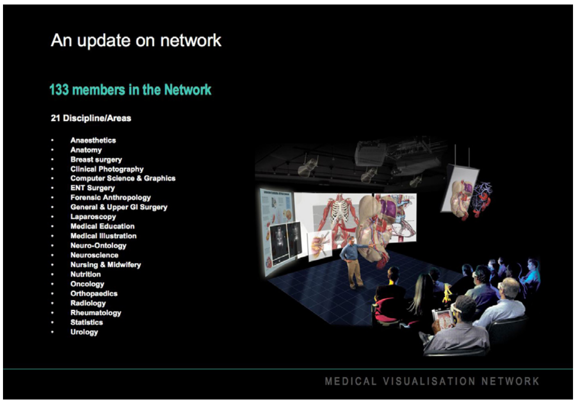

MEDICAL VISUALISATION NETWORK

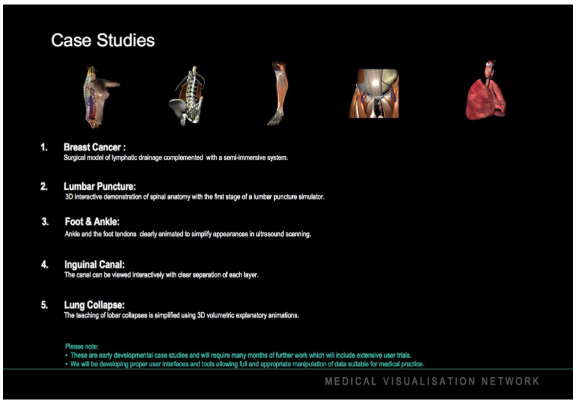

What we want to achieve
Make it easy for all of us to see the things we look at better…
Shorten the learning curve for beginners
Help the expert see more
Let us practice safely
Make life safer for patients
MEDICAL VISUALISATION NETWORK

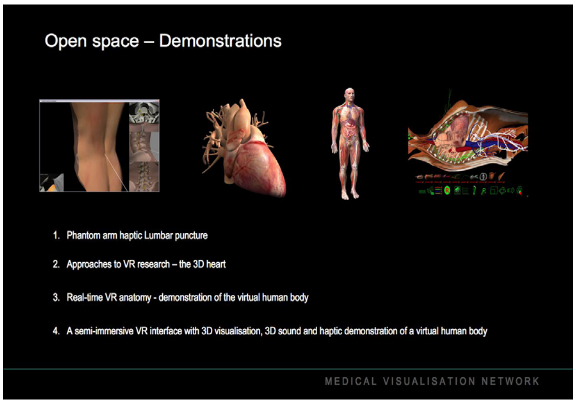

MEDICAL VISUALISATION NETWORK
second workshop
Welcome
Prof. Paul Anderson
Digital Design Studio
The Glasgow School of Art
The Royal College of Surgeons
Scottish Funding Council


Scottish Medical Visualisation Network
High Level Aims
• To establish an interdisciplinary network for new approaches to medical teaching and clinical diagnosis
• To create innovative techniques, tools and methodologies to support anatomical teaching and training
• To develop 3D visualisation and interaction in support of surgical rehearsal and pre-operative planning
• To promote understanding of lifestyle behaviours, disease processes and healthcare issues in a patient centred context and to the wider general public
• To enhance post-care management through visualisation to positively impact on patient recovery
MEDICAL VISUALISATION NETWORK


Aims for Today
• To continue to build our strategic 'connected' network in Scotland
• To present a range of selected case studies which will begin to form future research projects
• Open space: An opportunity to experience and discuss a range of demonstrations
• To launch the medical visualisation website
• To discuss further collaboration and funding opportunities
MEDICAL VISUALISATION NETWORK

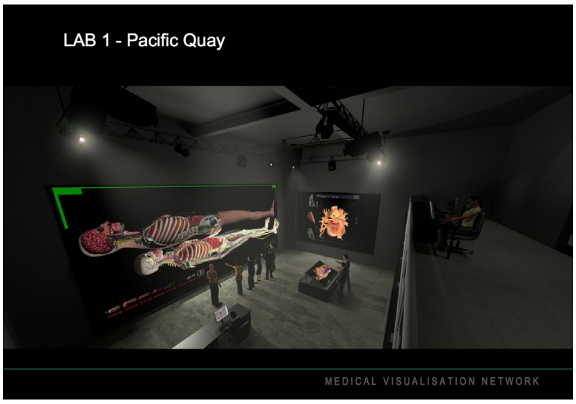

An update on network
133 members in the Network
21 Discipline/Areas
• Anaesthetics
• Anatomy
• Breast surgery
• Clinical Photography
• Computer Science & Graphics
• ENT Surgery
• Forensic Anthropology
• General & Upper GI Surgery
• Laparoscopy
• Medical Education
• Medical Illustration
• Neuro-Ontology
• Neuroscience
• Nursing & Midwifery
• Nutrition
• Oncology
• Orthopaedics
• Radiology
• Rheumatology
• Statistics
• Urology
MEDICAL VISUALISATION NETWORK

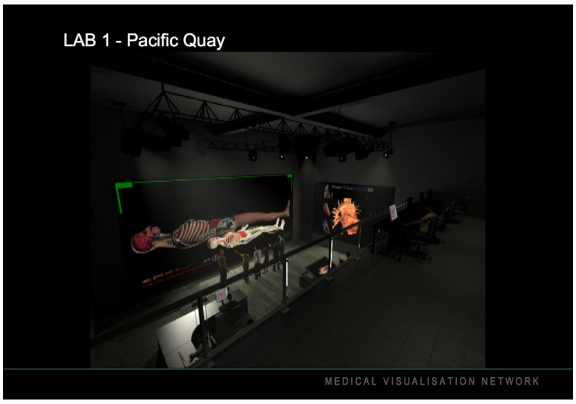

Case Studies
1. Breast Cancer :
Surgical model of lymphatic drainage complemented with a semi-immersive system.
2. Lumbar Puncture:
3D interactive demonstration of spinal anatomy with the first stage of a lumbar puncture simulator.
3. Foot & Ankle:
Ankle and the foot tendons clearly animated to simplify appearances in ultrasound scanning.
4. Inguinal Canal:
The canal can be viewed interactively with clear separation of each layer.
5. Lung Collapse:
The teaching of lobar collapses is simplified using 3D volumetric explanatory animations.
Please note:
• These are early developmental case studies and will require many months of further work which will include extensive user trials.
• We will be developing proper user interfaces and tools allowing full and appropriate manipulation of data suitable for medical practice.
MEDICAL VISUALISATION NETWORK


Open space – Demonstrations
1. Phantom arm haptic Lumbar puncture
2. Approaches to VR research – the 3D heart
3. Real-time VR anatomy - demonstration of the virtual human body
4. A semi-immersive VR interface with 3D visualisation, 3D sound and haptic demonstration of a virtual human body
MEDICAL VISUALISATION NETWORK


Medical Visualisation Network Website
MEDICAL VISUALISATION NETWORK
WELCOME TO THE SCOTTISH MEDICAL VISUALISATION NETWORK.
www.medicalvisualisation.co.uk
MEDICAL VISUALISATION NETWORK


The Future DDS - Pacific Quay
MEDICAL VISUALISATION NETWORK


LAB 1 - Pacific Quay
MEDICAL VISUALISATION NETWORK


LAB 1 - Pacific Quay
MEDICAL VISUALISATION NETWORK

second workshop

Medical Educational Research
Health through Innovation

Dr Ben Ward

New challenges and opportunities

- A changing landscape
- Increasingly exacting standards
- Increasing pressures of time and budget
- New opportunities for excellence

- How will we educate in the future?

MEDICAL VISUALISATION NETWORK

Proven techniques using new tools
Virtual Reality Augmentation

Is this practical? Who can use VR?

- Activity based learning
- Problem based learning
- Case based learning

VR can AUGMENT current educational strategy

MEDICAL VISUALISATION NETWORK

FAQs

- Does it really matter if it's interactive?
- Does it really matter if it's in 3D?
- Can everyone benefit from this approach?
- Why are there so few practical examples?
- Will this just sit in one of our cupboards?

MEDICAL VISUALISATION NETWORK

A strategic approach for Scotland

- A collective approach to R&D
- The formation of an expert community
- The practical application of innovation

MEDICAL VISUALISATION NETWORK

Collaborate, Research, Benefit

A new area of interdisciplinary research

Medicine, Computer Science, Design, Optics,
Human Computer Interfaces

MEDICAL VISUALISATION NETWORK

Medical Educational Research

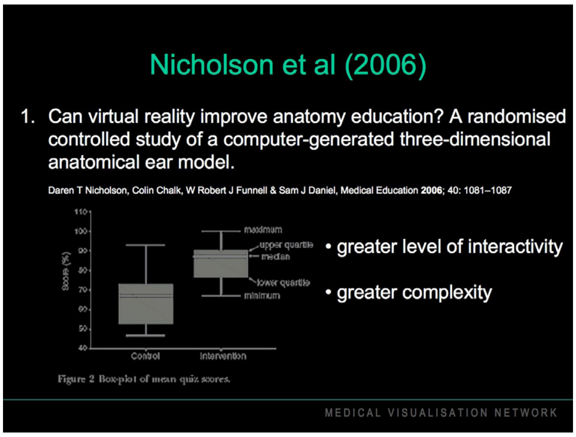
What is the current evidence?

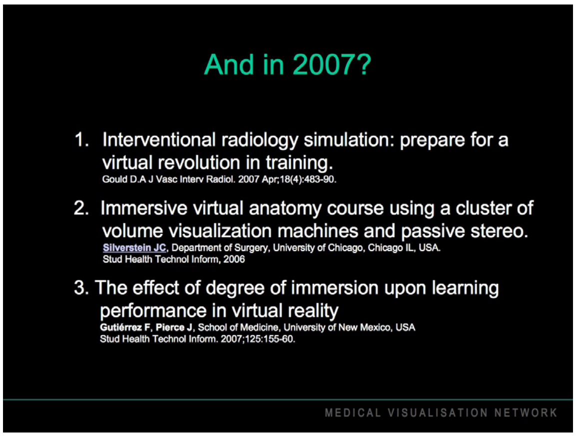
MEDICAL VISUALISATION NETWORK

Garg et al.

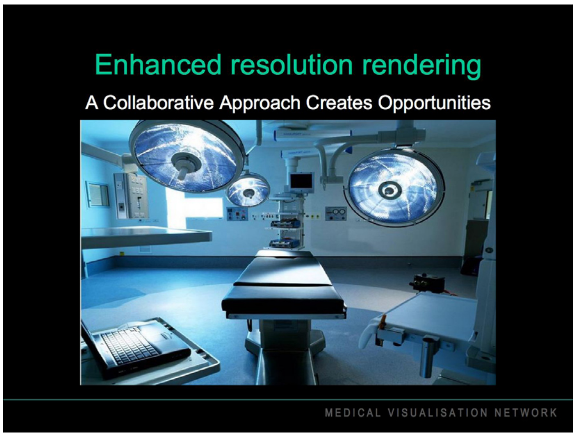
1. Do virtual computer models hinder anatomy learning?
   Garg A, Norman GR, Spero L, Maheshwari P. Acad Med 1999;74(10 Suppl.):S87–9.
2. How medical students learn spatial anatomy.
   Garg AX, Norman G, Sperotable L. Lancet 2001;357(9253):363–4.
3. Is there any real virtue of virtual reality? The minor role of multiple orientations in learning anatomy from computers.
   Garg AX, Norman GR, Eva KW, Spero L, Sharan S. Acad Med 2002;77(10 Suppl.):S97–9.

MEDICAL VISUALISATION NETWORK


Nicholson et al (2006)
1. Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model.
Daren T Nicholson, Colin Chalk, W Robert J Funnell & Sam J Daniel, Medical Education 2006; 40: 1081–1087
maximum
upper quartile
median
lower quartile
minimum
Control
Intervention
Figure 2 Box-plot of mean quiz scores.
• greater level of interactivity
• greater complexity
MEDICAL VISUALISATION NETWORK

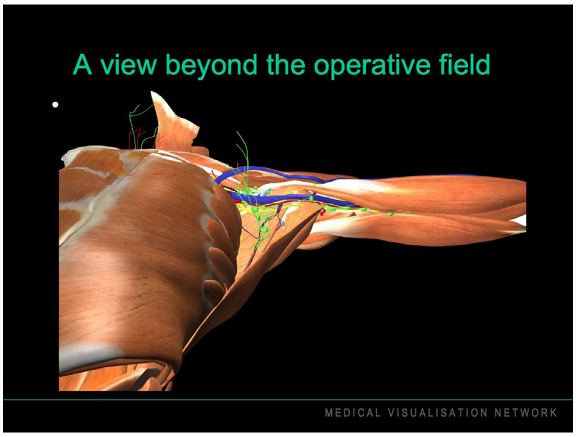

And in 2007?
1. Interventional radiology simulation: prepare for a virtual revolution in training.
Gould D.A J Vasc Interv Radiol. 2007 Apr;18(4):483-90.
2. Immersive virtual anatomy course using a cluster of volume visualization machines and passive stereo.
Silverstein JC, Department of Surgery, University of Chicago, Chicago IL, USA.
Stud Health Technol Inform, 2006
3. The effect of degree of immersion upon learning performance in virtual reality
Gutiérrez F, Pierce J, School of Medicine, University of New Mexico, USA
Stud Health Technol Inform. 2007;125:155-60.
MEDICAL VISUALISATION NETWORK

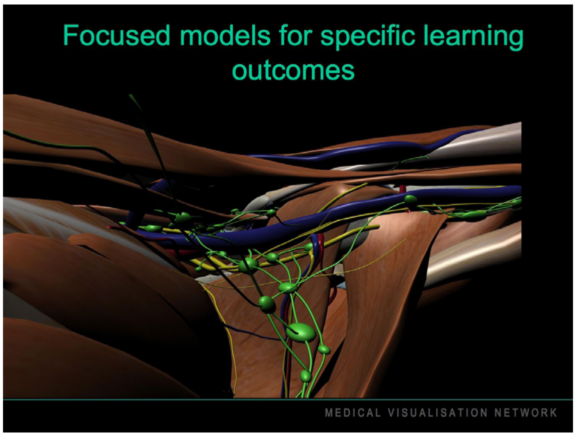

Not all VR is the same!
MEDICAL VISUALISATION NETWORK

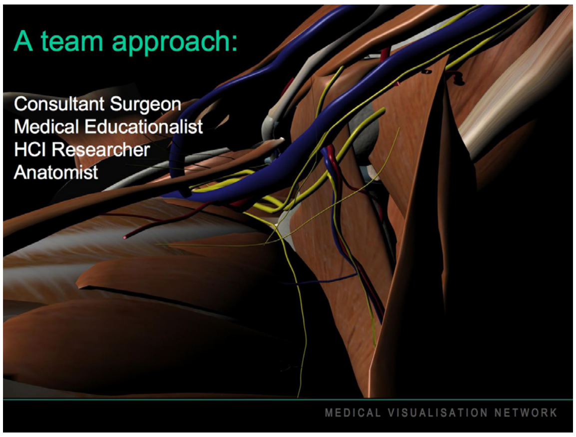

Enhanced resolution rendering
A Collaborative Approach Creates Opportunities
MEDICAL VISUALISATION NETWORK

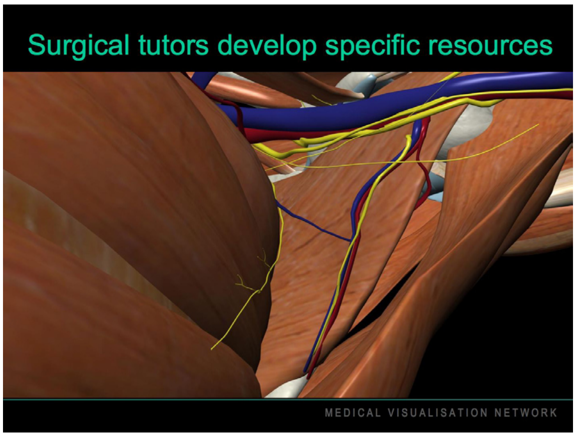

A trainee centred approach
MEDICAL VISUALISATION NETWORK

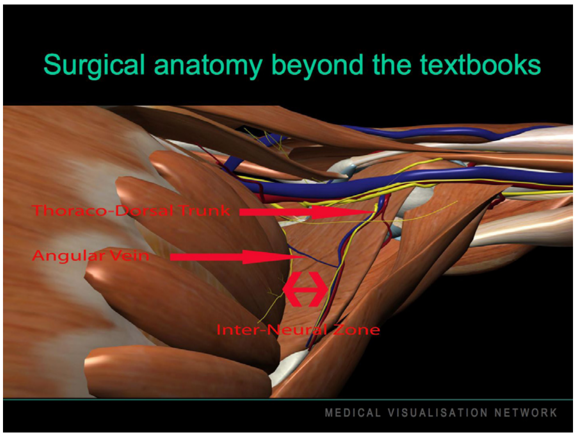

Promoting patient safety virtually
MEDICAL VISUALISATION NETWORK

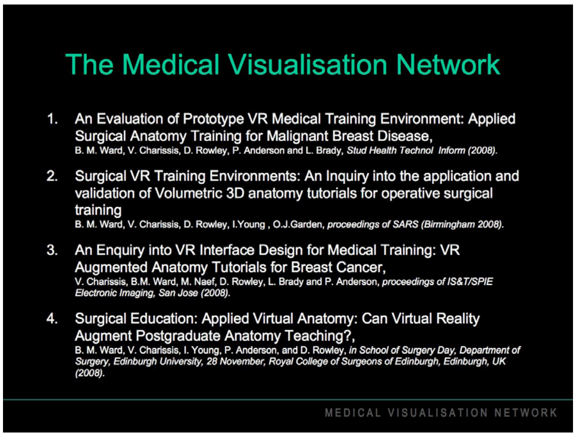

A view beyond the operative field
MEDICAL VISUALISATION NETWORK

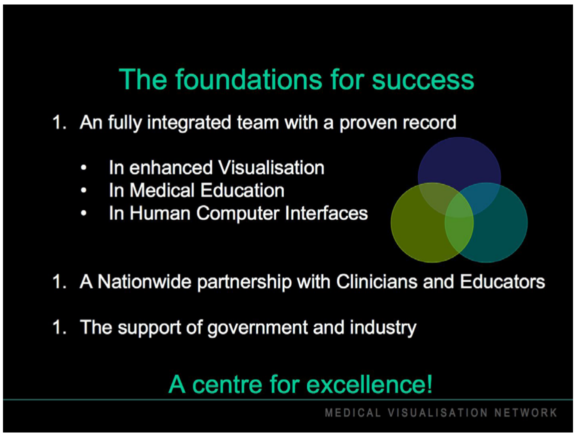

Focused models for specific learning outcomes
MEDICAL VISUALISATION NETWORK


A team approach:
Consultant Surgeon
Medical Educationalist
HCI Researcher
Anatomist
MEDICAL VISUALISATION NETWORK


Surgical tutors develop specific resources
MEDICAL VISUALISATION NETWORK


Surgical anatomy beyond the textbooks
Thoraco-Dorsal Trunk
Angular Vein
Inter-Neural Zone
MEDICAL VISUALISATION NETWORK


The Medical Visualisation Network
1. An Evaluation of Prototype VR Medical Training Environment: Applied Surgical Anatomy Training for Malignant Breast Disease,
B. M. Ward, V. Charissis, D. Rowley, P. Anderson and L. Brady, Stud Health Technol Inform (2008).
2. Surgical VR Training Environments: An Inquiry into the application and validation of Volumetric 3D anatomy tutorials for operative surgical training
B. M. Ward, V. Charissis, D. Rowley, I.Young , O.J.Garden, proceedings of SARS (Birmingham 2008).
3. An Enquiry into VR Interface Design for Medical Training: VR Augmented Anatomy Tutorials for Breast Cancer,
V. Charissis, B.M. Ward, M. Naef, D. Rowley, L. Brady and P. Anderson, proceedings of IS&T/SPIE Electronic Imaging, San Jose (2008).
4. Surgical Education: Applied Virtual Anatomy: Can Virtual Reality Augment Postgraduate Anatomy Teaching?,
B. M. Ward, V. Charissis, I. Young, P. Anderson, and D. Rowley, in School of Surgery Day, Department of Surgery, Edinburgh University, 28 November, Royal College of Surgeons of Edinburgh, Edinburgh, UK (2008).
MEDICAL VISUALISATION NETWORK


The foundations for success
1. An fully integrated team with a proven record
• In enhanced Visualisation
• In Medical Education
• In Human Computer Interfaces
1. A Nationwide partnership with Clinicians and Educators
1. The support of government and industry
A centre for excellence!
MEDICAL VISUALISATION NETWORK

second workshop

Anatomy Reconstructed

Professor Ian Parkin

Digital Design Studio The Glasgow School of Art · The Royal College of Surgeons · Scottish Funding Council

Anatomy Reconstructed

- Gold standard: 3-D, cadaveric, hands-on, active, directed student learning
- Add insight and understanding to promote deeper learning, and safe clinical practice
- Cadaveric specimens are not always available
- Different stages of learning and training may benefit from a different approach

MEDICAL VISUALISATION NETWORK

Anatomy: Reconstructed (Workshop 1)

- Reconstruct to offer 3-D, active, spatial learning
- Simulate: function, movement; clinical procedure or surgical approach
- Add "life" and keep abreast of technology
- Difficult concepts: not visible on cadaver; 3-D; moving with development, posture and age
- Inguinal region; peritoneum and lesser sac; perineum; potential spaces
- Embryology (similar issues): watch A become B or C

MEDICAL VISUALISATION NETWORK

Anatomy: Reconstructed (Workshop 1)

- Reconstruct to offer 3-D, active, spatial learning
- Simulate: function, movement; clinical procedure or surgical approach
- Add "life" and keep abreast of technology
- **Difficult concepts:** not visible on cadaver; 3-D; moving with development, posture and age
- **Inguinal region;** peritoneum and lesser sac; perineum; potential spaces
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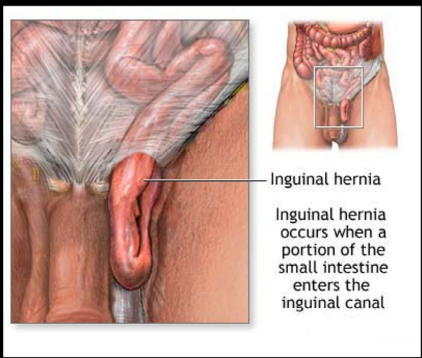
MEDICAL VISUALISATION NETWORK

Why?



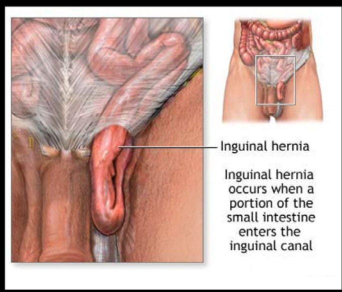
MEDICAL VISUALISATION NETWORK

Why?

Clinical examination

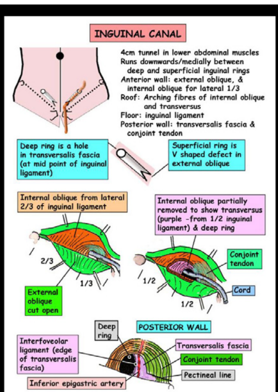
Differential diagnosis

Surgical approaches



MEDICAL VISUALISATION NETWORK

Current Visual Aids



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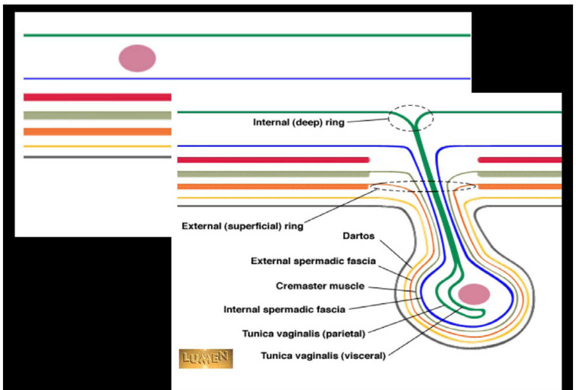

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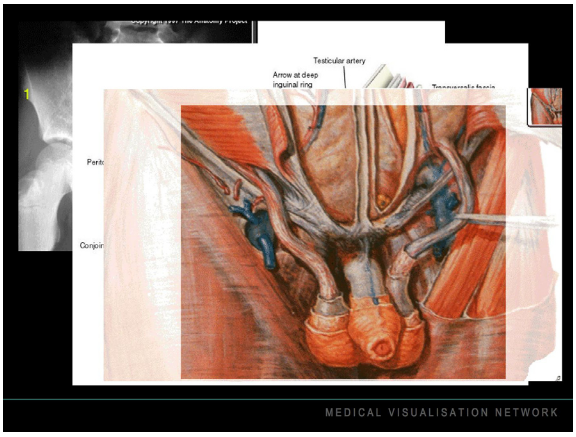

Current Visual Aids

- Static
- Artificial
- Non-interactive
- May be inaccurate

MEDICAL VISUALISATION NETWORK

Medical Visualisation Network

- Build and alter to become accurate
- Interactive
- Visualise different anatomical or surgical approaches:
  - Adapted for different audiences
  - Laparoscopic camera view
- Whole layers may be added or removed

MEDICAL VISUALISATION NETWORK

Medical Visualisation Network Future Plans

- Create the interfaces
  - User friendly, professional packages
  - User trials
- Full-time research and development team

MEDICAL VISUALISATION NETWORK

Medical Visualisation Network

- See what you think of this "proof of concept" demonstration
  - Which shows raw data, collected, corrected, manipulated
  - And is very much "work in progress"

Thank you, your comments and suggestions will be greatly appreciated

MEDICAL VISUALISATION NETWORK

14 November 2007

Speakers

Prof. Paul Anderson

Paul is the Director of the Digital Design Studio, which he established in 1997. He has an international profile in digital visualisation and interaction research concerned with fundamental human computer interface issues, particularly those associated with 3D interfaces, haptics and gesture-based interaction. He has won major research funding from the EU, EPSRC, NESTA, Scottish Funding Council and Scottish Enterprise. His rsearch interests are focused on medical, automotive and defence fields. He has collaborated with a number of world-class research organisations, and has published internationally on the subject of digital visualisation and interaction. Paul leads the Scottish Medical Visualisation Network in partnership with David Rowley.

Prof. David Rowley

David is Professor at the University Dept. of Orthopaedic and Trauma Surgery, Ninewells Hospital and Medical School, Dundee, Director of Education, Royal College of Surgeons of Edinburgh and Visiting Professor of Surgical Education, University of Edinburgh. He is a lower-limb construction surgeon now entirely in the elective field and runs a global audit and outcomes unit assessing the long term results of hip and knee replacements. He has a particular interest in knee arthroplasty and foot surgery and biomechanics. He has carried out infection studies for the International Committee of the Red Cross and undertaken several field missions. David leads the Scottish Medical Visualisation Network in partnership with Paul Anderson of the Digital Design Studio.

Mr John Orr

John is President of the Royal College of Surgeons of Edinburgh. He is Consultant Paediatric Surgeon at the Royal Hospital for Sick Children in Edinburgh. His expertise is in general paediatric surgery with an interest in paediatric urology, with published work in surgery, emergency paediatric surgery and paediatric urology. John is Chairman of the Scottish Audit of Surgical Mortality, and a member of the Academy of Medical Royal Colleges, the Joint Committee on Surgical Training, JCSM and the Surgical Forum. He has previously been Chairman of the SAC in Paediatric Surgery, Medical Director of the Royal Hospital for Sick Children, CD Surgical Services Western General Hospital, and Chairman of the Intercollegiate Committee for Basic Surgical Training.

Mr Ben Ward

Ben is Clinical Lecturer in the Department of Surgery at the University of Edinburgh leading 5th Year Undergraduate teaching in general surgery. His interests include e-learning and Virtual Reality applied to surgical anatomy teaching and practice. He is part of the development team for a new online Masters degree in basic surgical sciences, the Edinburgh Surgical Sciences Qualification. He is a member of the ESSQ content and assessment groups and is particularly interested in online case-based learning. He has published internationally on behalf of the Scottish Medical Visualisation Network and is a Board member and lead researcher for the Network.

Dr David Chanock

David was educated in South Africa and studied radiology in Durban. He emigrated to Scotland in 1997 and has been working there as a Diagnostic Radiologist since his move. He is a general radiologist with an interest in cross sectional imaging. He has a keen interest in teaching and is the Acting Academic Sub-Dean for Glasgow University at Ayr Hospital and the NES Foundation Tutor. He is an examiner in the final year medical examinations at Glasgow University and is on the steering group of the MS Managed Clinical Network. David is a Board member of the Scottish Medical Visualisation Network.

Prof. Ian Parkin

Ian qualified in medicine in 1975 but after pre- and post-registration medical and surgical positions, chose to follow a career in anatomy, becoming professor of applied clinical anatomy, University of Dundee and Royal College of Surgeons of Edinburgh, in 2005. He is a Fellow of the British Association of Clinical Anatomists and Honorary Fellow of the Institute of Anatomical Sciences. His expertise includes the delivery of three-dimensional, functional and clinically relevant anatomy to undergraduate medical students and postgraduate trainees. Ian is a Board member of the Scottish Medical Visualisation Network.

Digital Design Studio ■ Royal College of Surgeons

14 November 2007

Partners

Digital Design Studio, Glasgow School of Art

The Digital Design Studio (DDS) was established in 1997 as a specialist postgraduate research and commercial centre of Glasgow School of Art. It has an international reputation for research and teaching in digital technologies for advanced 3D visualisation and interaction.

DDS activities revolve around interactive virtual reality: virtual environments with 3D sound where digital models are displayed in 3D space, and interaction with the models is possible through gesture, touch (tactile and force feedback) and physical "props". A wide range of research and commercial projects explore the potential of such environments in the fields of architecture, medicine, education, games and entertainment, heritage and transport. The DDS has been successful in securing research funding from SFC, EPSRC, AHRC, NESTA, and the EU. It has a large portfolio of projects with business and industry in Scotland, the UK and Europe, centred on expertise in real-time 3D visualisation, 3D sound, modelling and animation.

This research requires a broad range of expertise, and the DDS has an international staff comprising multidisciplinary designers, 3D digital modellers, animators, programmers, architects, artists, scientists and engineers with a wide range of knowledge and experience who enjoy the challenges of visualisation. Research activity at the DDS is underpinned by one and two year masters degrees in animation and a growing Ph.D. community.

The Royal College of Surgeons of Edinburgh

In 1505, the incorporation of the Barber-Surgeons of Edinburgh came into being with the granting of its Seal of Cause by the Town Council of Edinburgh. Since then, the Royal College of Surgeons of Edinburgh has been dedicated to the maintenance and promotion of the highest standards of surgical practice, through its keen interest in education, training and rigorous examination and through its liaison with external medical bodies. Whilst being keenly aware of its antiquity (the College celebrated its quincentenary in 2005), the College prides itself also on its innovation and adaptability.

At the beginning of the 21st Century, the College has over 17,000 Fellows and Members, only half of whom live in the British Isles. Whatever their location, the Membership is concerned to fulfil the prime purpose of the College. Quite simply this is the maintenance and promotion of the highest standards of surgical practice and surgical training. Until very recently, the College has been concerned almost entirely with the setting of standards and the conduct of examinations designed to ensure that these standards are being maintained. Today the College is increasingly concerned with the provision of surgical education and training in addition to maintaining and enhancing its historic role.

Scottish Funding Council

The Scottish Further and Higher Education Funding Council (SFC) is a non-departmental public body responsible to – but operating at arm's length from – the Scottish Government. It distributes more than £1.6 billion of public funds annually to colleges and universities on behalf of the Scottish Government.

The Council provides financial support for learning and teaching, and research and associated activities in Scotland's 19 higher education institutions (HEIs). As well as providing financial support for learning and teaching in Scotland's 43 further education (FE) colleges, the Council provides resources to enable colleges to offer bursaries to students on non-advanced courses.

The Council is responsible for working with Scotland's colleges and universities to develop strategies in support of ministerial priorities and securing coherent, high quality provision of further and higher education and supporting the undertaking of research. In addition, SFC has a statutory function to provide Scottish Ministers with advice and information on matters relating to further and higher education. It is also responsible for ensuring that the quality of further and higher education provision is assessed and enhanced, and is required to monitor the financial health of both sectors.

Digital Design Studio ■ Royal College of Surgeons

second workshop
14th November 2007

Certificate of Attendance

This is to certify that

attended this workshop

DIGITAL DESIGN STUDIO THE GLASGOW SCHOOL OF ART

THE ROYAL COLLEGE OF SURGEONS

Scottish Funding Council
Promoting further and higher education

Research Partners

The Scottish Medical Visualisation Network is partnering with a range of organisations to ensure both academic relevance and commercial outreach of all its activities. The following sections list the established partnerships at the end of the initial feasibility study.

Royal College of Surgeons of Edinburgh is dedicated to the maintenance and promotion of the highest standards of surgical practice, through its keen interest in education, training and rigorous examination and through its liaison with external medical bodies.

A founding partner of the Network, RCS is committed to its future growth.

NHS Education for Scotland (NES) helps to provide better patient care by providing educational solutions for workforce development by designing, commissioning, quality assuring and where appropriate providing education for NHS Scotland staff.

NES is represented on the Network Board by Professor Philip Cachia. NES has already funded two research projects (see Sections 0 and 0 above).

Centre for Health Science, Inverness (CfHS) is a focus for excellence in healthcare and biotechnology research, education, training and business development, the first of its kind in the UK. Located adjacent to Inverness's Raigmore Hospital, this multi-million pound facility represents a major milestone in adding to the already significant cluster of health science activity in the Highlands and Islands of Scotland.

The Centre for Health Science has already opened Phase 1 of its development with Phases 2 and 3 due for completion in the summer of 2008. The aim of the Centre is to instigate collaboration, knowledge transfer, improved clinical outcomes, publications and commercialisation. The endeavour and innovation of its partners has pushed the Centre into the national and international arenas with a number of new developments already in the pipeline.

CfHS has funded a research project on the anatomy of the shoulder (see Section 0 above) and could become a centre for dissemination for the Network in the future.

Castle Craig Hospital provides inpatient treatment for those suffering from alcohol and drug dependence and other addictive disorders. Established for 19 years, the hospital and treatment are under medical management. The hospital is a prime and extra contractor to the National Health Service, is recognised by the Dutch healthcare system and is a preferred provider both to major UK medical insurers and to the US Department of Defence.

Negotiations are ongoing with this partner for a research project on the effects of addiction on the brain (see Section 0 above).

Scottish Health Innovations Limited (SHIL) has been established to support the development and commercialisation of innovations arising within the NHS in Scotland. With funding from the Scottish Executive's Chief Scientist Office, Scottish Enterprise, Highlands and Islands Enterprise and the Department of Trade and Industry, it seeks to identify and develop new technologies which can be exploited through partnerships with the private sector. SHIL is able to provide high quality advice and assistance on market application and intellectual property protection to investors and researchers throughout NHS Scotland.

Thereafter, considerable value is added to these innovations by providing managerial and funding support during their development and commercialisation. It seeks to improve quality and value for money of patient care throughout NHS Scotland, increase the generation of income to the NHS, stimulate economic wealth in Scotland through the creation of new jobs and enterprises, and delivering new market opportunities for businesses interested in licensing NHS Scotland technologies.

We are talking with SHIL and Yorkhill Sick Children's Hospital's Physiotherapy Department about Hippotherapy – the evaluation and development of a physiotherapy device.

GE Healthcare is dedicated to helping our partners in healthcare predict, diagnose, inform and treat disease earlier than ever. They are ushering in a new era of healthcare through medical imaging and information technologies, medical diagnostics, patient monitoring and life-support systems, disease research and drug discovery.

They are currently considering a network proposal for a collaborative venture into ultrasound anatomy and techniques for regional anaesthesia. They have agreed to the collaboration in principal at UK and European level; US backing is pending.

Sumarian services deliver actionable insight out of a business' most underused asset - data. They interrogate, analyse, model and interpret data to allow a business make the most informed, fact-based decisions for its IT and business future.

Meetings have been held with this company to explore future IT and data solutions for the Network.

TPLD is one of the global leaders in the emerging Serious Games market. We are focused on delivering Games-Based Learning (GBL) solutions and technologies to aid organisations in their drive for competitive advantage. Their software products and industry solutions help customers and partners create an effective, experiential and high-impact approach to professional and personal development.

Meetings are underway with this company to explore the use of computer games platforms in future research and commercial projects.

VASCUTEK, is based at a custom built facility in Scotland and is one of the world's leading designers, manufacturers and marketers of vascular products for the treatment of cardiovascular disease. Originally formed in 1982, the company is guided by an ethos of technical excellence, stringent quality control and total customer service. It has a continuous programme of Research and Development and maintains communication with surgeons around the world in order to deliver innovative products trusted by surgeons. Vascutek is a leading manufacturer of vascular prostheses used by cardiovascular surgeons in the treatment of aneurismal or occlusive arterial disease.

Meetings have been held with this company to explore future commercial projects.

Picsel Technologies is a dynamic mobile solutions provider, whose pioneering software brings content on mobile to life. Established in 1998, the company now employs over 300 staff at its headquarters in Glasgow, Scotland and in offices throughout Japan, China, Korea, Malaysia and the US. The company's technology is found on 125 million devices worldwide, with a customer list that includes KDDI, Motorola, Nokia, NTT DoCoMo, Palm, Samsung, Sony Ericsson and Sharp. Picsel's aim is to empower operators, OEMs and content owners to create visually stunning and interactive applications that drive uptake of new content services.

Meetings have been held with this company to explore future commercial projects.

MidTECH is one of a network of nine English regional NHS innovation hubs, established by the Department of Health to identify, protect and commercialise innovative ideas from within the NHS. This includes helping to patent or otherwise protect ideas, linking up with industries that may help to commercialise; this could take the form of a licence, joint venture, or spin out. MidTECH works on behalf of the client Trust to evaluate an idea and ensure any associated intellectual property is protected.

MidTech is already involved in the Designing Out Infection project detailed in Section 8.1.