Individual project 1: Combined infrared and visible instrument segmentation system

Supervisors: Dr Daniel Elson and Dr Peter Mountney (Siemens)

Aims and objectives

- To build an endoscope that uses visible and near-infrared light to detect the position of surgical tools within the operative field;
- Possible extension: to adapt the instrument to allow detection of near infrared fluorescence from ICG, a fluorophore that is increasingly being used for image guided intervention.

Background

Accurately locating the site of surgical tool-tissue interaction is of interest for computer assisted intervention, as well as for optical probe guidance and microscopic image mosaicing. Approaches based on optical markers require markers to be attached to the instrument and direct line-of-sight. Electromagnetic tracking also uses additional markers and an external tracking system, but the position information may be distorted by metallic or magnetic objects. Mechanical localisers are bulky and complex to use during standard laparoscopic investigations. Surgical tool segmentation has previously been attempted by using colour and geometrical information, and while these methods are promising, they are affected by contamination from blood. This project will investigate the use of near infrared light to detect tool position using the increased penetration depth of this type of light through blood on the surgical instruments.

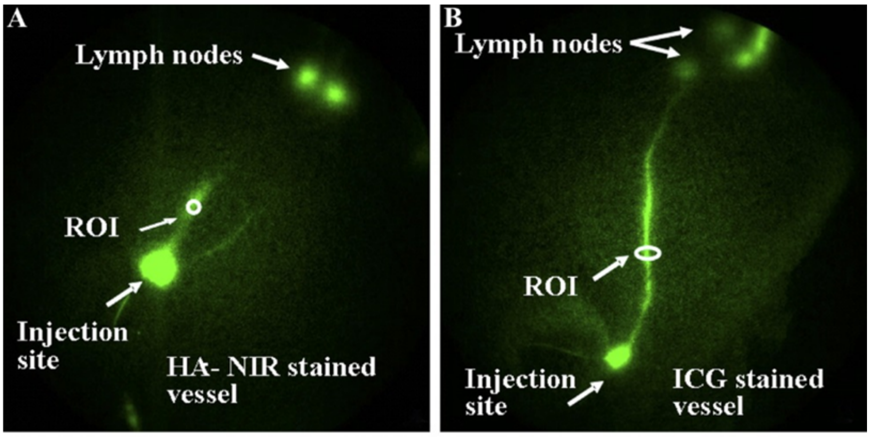
Skeleton project plan

The project will use a modified light source that is able to either simultaneously provide visible and near-infrared illumination of the sample, or filter the light into different spectral bands. A camera system such as the “Spectrocam” (Ocean Thin Films Inc.) will be attached to a laparoscope to acquire spectrally-resolved images of the surgical scene. Segmentation of the surgical instrument will then be attempted based on spectral analysis of each pixel within the acquired images.

Example of Hue, Saturation and Value planes from a typical surgical scene containing an instrument [1]

The same hardware set-up can also be adapted for near-infrared fluorescence imaging of ICG, a fluorophore that is being increasingly used for image-guided surgery (e.g. Intuitive Firefly). A possible extension of this project would be to simultaneously locate the surgical instrument with respect to the site of fluorescence within the surgical field. Again, this can be achieved by modifying the type of light provided by the light source and by using the Spectrocam to spectrally resolve the emitted light.

The project involves simulation and design (medium), building an optical instrument (medium), data acquisition (low), image spectral analysis (advanced), validation (medium) and testing in vivo (advanced).



Example of lymph vessel and node imaging using injected ICG and near infrared fluorescence [2]

Hardware/software requirements

- Spectrocam, laparoscope and custom light source
- LabVIEW
- Matlab or C++

[1] Giannarou et al. MICCAI Workshop on Optical Tissue Image Analysis in Microscopy, Histopathology and Endoscopy, 2009.

[2] Sharma et al. American Journal of Physiology - Heart and Circulatory Physiology, H3109-H3118 (2007)

Individual project 2: Project name: Humanoid Robot Control with BioMotion+

Supervisors: Dr Zhiqiang Zhang, Prof Guang-Zhong Yang

Aims and objectives:

Design and implement a seamless control interface with BioMotion+ (the next generation wireless biomotion sensors) for controlling a humanoid robot (NAO H25).

Background:

One of the significant challenges of robotic control for humanoids is concerned with replicating natural human posture and gait patterns. This can be achieved by using a number of different approaches but recently the method of learning by demonstration has attracted significant research interests as with the use of smart sensing technologies. In this project, we will use the new BioMotion+ sensors developed by the Hamlyn Centre to capture the body movement and control the NAO humanoid robot.

Skeleton project plan

The project will first involve detailed user requirement analysis of the device and more importantly the unmet technical needs of the existing learning-by-demonstration methods. This will then followed by your design and implementation, as well as considerations for the ease of use of your proposed platform for seamless capturing of the body posture/movement for controlling the NAO humanoid robot. Key milestones of the project include:

- Technical gap analysis and usage scenarios;
- BioMotion+ and NAO interfacing and gestures to be used for controlling the camera;
- Prototype design and implementation;
- System integration and demonstration of the control mechanism;

Hardware/software requirements

- BioMotion+
- NAO H25 Robot

(you may want to see the videos from the last year MRs student https://www.youtube.com/watch?v=5V5bSSqUTDc , https://www.youtube.com/watch?v=06q6APRKRZo http://www.youtube.com/watch?v=N1Hx_r2Znp4 and http://www.youtube.com/watch?v=IzQ9F3HN4tk to get some basic idea. The purpose is to move beyond what we have achieved and make it much more impressive!)

Individual project 3: How Resilient to Attack are Surgeons' Brain Networks?

Supervisors: Javier Andreu-Perez, Daniel Leff, Felipe Orihuela-Espina

Background, Aims and Objectives

Brain function is known to be dynamic and evolves as surgeons learn to acquire technical skills. Novice surgeons have a tendency to recruit regions of executive control such as the prefrontal cortex (PFC) more readily than experts. The latter having refined skills through years of practice seemingly tend to rely more on secondary motor areas such as the supplementary motor area (SMA), an area where well-learned routines and motor sequences are stored as well as the motor cortex (M1) which is essential for execution of complex motor routines. More recent data from studies investigating surgeons' brain function during highly complex manoeuvres in minimally invasive surgery has revealed that not only do the location of activation foci change across learning but also the communication (i.e. functional connectivity) between brain regions similarly adapts (an effect known as neuroplasticity). The evolution in functional connectivity can be captured in topological changes in the wiring of brain networks, and insights into learning-related changes in the performance of these networks can be obtained through cross-sectional studies of subjects with different expertise. To date the most striking expertise-dependent difference in brain networks has been the way they are optimised for local and long-range connectedness, a property known as Small-worldness. Put simply, the brains of experts appear to be significantly smaller world than those of novices, suggesting that they can more readily exchange information between brain regions linked to the task. What remains unknown is whether the expert brain network is more robust or resilient than that of the novice. A method for testing the hypothesis that the expert brain copes better when threatened or challenged is to deliberately introduce an external stressor or supplementary cognitively demanding task. Computational systems can be useful for determining the impact of these behavioural changes into the brain; for example, by analysing the effect of "cascade attacks" on the network whilst re-interrogating its fitness.

Skeleton project plan

The plan is to interrogate the performance of expert and novice brain networks perturbing the network topology. To do so, a series of cascading attacks will be used to test the hypothesis that brain networks of expert surgeons are less prone to systemic collapse than those of the novices. The project will involve acquiring expert and novice optical brain data using Optical Topography (ETG-4000, Hitachi Medical Corp) during MIS tasks. It is proposed to use Imperial College Neuroimage Analysis software (ICNA) Software to pre-process the data. Graphs representing functional brain networks will then be generated and interrogated for their performance (costs, efficiency, burden, hubs, small worldness etc.). The student will then be required to elaborate the necessary software tools to carry out this analysis, including an experimental test ensuring reproducibility of the results. All code must be properly documented and written according to the standard guidelines of software engineering.

Hardware/software requirements

- Functional Optical Topography (Hitachi, ETG-4000 OT system) Hardware available.
    - A workstation with the following licensed software: Microsoft Office, MATLAB

Individual project 4: Electromagnetic Tracking and Robotic Actuation of Endomicroscopy Probes

Supervisors Michael Hughes and Guang-Zhong Yang

Aims and objectives

Investigate the potential for electromagnetic (EM) tracking and robotic actuation to assist with mosaicing of endomicroscopy images.

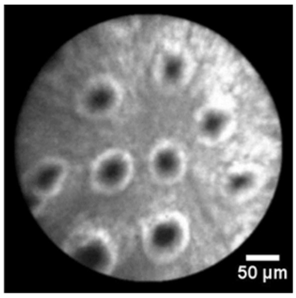


Fig 1. Porcine large bowel mucosa (ex vivo)

Background

Endomicroscopy, which gives us high resolution images of human tissue [1], is beginning to have a real clinical impact in the diagnosis of diseases such as Barrett's Oesophagus. However, one of the limitations of the technology is the relatively small field of view, which is typically less than 500 µm. This can be extended by mosaicing: stitching together adjacent video frames to create a larger image [2]. But this is difficult to do in practice, requiring careful probe manipulation on a sub-mm scale.

Fig 2. Endomicroscopy probe from one of our in-house systems.

In 2010, Quirk et al. demonstrated that electromagnetic tracking can be used to measure the location of an optical coherence tomography (OCT) probe [3], and a second paper in 2012 showed this can be done with an accuracy of 18 µm [4]. Despite this success, the idea has not yet been applied to endomicroscopy. The aim of this project will be to investigate whether an endomicroscope probe can be accurately tracked, and whether the tracking data can be used to assist with mosaicking. We have already performed an initial study to show that such tracking is feasible in principle (Fig. 3), and the aim now is to fully explore the possibilities and develop a practical approach. This may be applied either to free-hand scanning or scanning under robotic actuation, depending on the interests of the student.

Brief project plan

- Optimisation of the location of attachment of the EM tracker to the endomicroscope probe.
- Development of a calibration procedure.
- Measurement of tracking accuracy over a range of distances and experimental conditions.
- Integration of tracking and/or robotic actuation into a mosaicing algorithm.
- *Ex vivo* phantom and tissue validation.

This is only indicative, the project will be adapted to meet the interests/skills of the student, for example by combing EM tracking with robotic-controlled mosaicing.

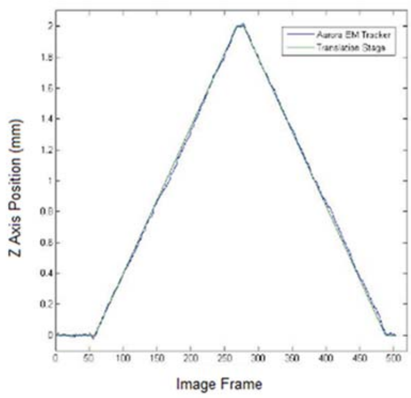


Fig 3. Results of feasibility experiment showing good correlation between EM tracking data and position of translation stage.

Hardware/software requirements

- Aurora EM tracking system on a small number of occasions for data collection.

- Custom endomicroscopy system and 2D translation stage can be made available as required.
- Robotic actuation, design and implementation
- Cross correlation based mosaicking software available in Matlab and Labview.

References

[1] Jabbour, Joey M., et al., "*Confocal endomicroscopy: instrumentation and medical applications,*" Annals of Biomedical Engineering **40**, 378-397 (2012).

[2] Vercauteren, Tom, et al., "*Robust mosaicing with correction of motion distortions and tissue deformations for in vivo fibered microscopy,*" Medical Image Analysis **10, 673** (2006).

[3] Lau, Brandon, et al.,"*Imaging true 3D endoscopic anatomy by incorporating magnetic tracking with optical coherence tomography: proof-of-principle for airways,*" Opt. Express **18**, 27180 (2010).

[4] Yeo, Boon Y., et al., "*Enabling freehand lateral scanning of optical coherence tomography needle probes with a magnetic tracking syste*m," Biomed. Opt. Express **3,** 1565 (2012).

Individual project 5: Hamlyn Catheter Robot

Supervisors: Hedyeh Rafii-Tari, Jindong Liu, Guang-Zhong Yang

Aims and objectives

Development of an intuitive, force-feedback robotic catheterization platform for collaborative endovascular navigation.

Background

Over the last decade, there has been a growing interest in teleoperated robotic catheterization systems for endovascular intervention, by offering advantages to conventional catheterization techniques including reduced radiation exposure, increased precision and stability of motion and added operator comfort. Most existing commercial solutions however have been designed without considering natural manipulation techniques and operator-tool interactions used during bedside practice. Ergonomic consideration of the input interface and incorporation of natural manipulation patterns and skill models into the system is important in ensuring that the system is intuitive to use. As a result, recent designs of endovascular master/slave platforms are moving towards more ergonomic interfaces that take advantage of experience-related skills of operators, while in some instances they attempt to augment the operator's ability to conduct the procedure by providing haptic feedback. The purpose of this project is to expand an existing prototype of a hands-on master-slave endovascular robotic system with improved motion/force sensing and haptic feedback, to allow for intuitive human-robot interaction and collaborative control. The incorporation of motion/contact force sensing and force feedback is significant for enhancing the safety of the procedure while compensating for the haptic cues that would be felt by the operator during conventional catheter navigation. The project will also explore integration of skill models, learned from multiple demonstration of the procedure, for shared control between operator and robot.

Skeleton project plan

The project will expand on the existing hands-on endovascular robotic framework (examples of which are shown in Figure 1), with improved hardware, motion/force sensing, control algorithms, and force feedback capabilities. The candidate needs to have a strong background in hardware/sensor design and system integration, and be proficient in development of control algorithms and user interfaces.

Figure 1 – Example of robotic master-slave force feedback prototypes (left) and a catheter driving platform (right)

The specific steps and requirement of the project are as follows:

- Mechanical design of catheter robot by integrating force/motion sensors;
- Control algorithm development and implementation of force feedback;
- Integration of existing skill models and learning algorithms;
- System integration and user interface design;
- Validation on phantoms and performance analysis.
- Thesis writing

Hardware/software requirements

- Hardware design/Cad modelling (Solidworks)
- Mechatronic design
- 3D rapid prototyping
- Sensor and actuator control
- LabView
- Programming (Matlab / C++)

Individual project 6: Three dimensional endoscopic imaging through a single fibre

Supervisors: Daniel Elson, Lei Su (University of Liverpool)

Aims and objectives

To produce an endoscopic imaging system that is able to record images of a sample through a single optical fibre, including modification of the focal plane.

Background

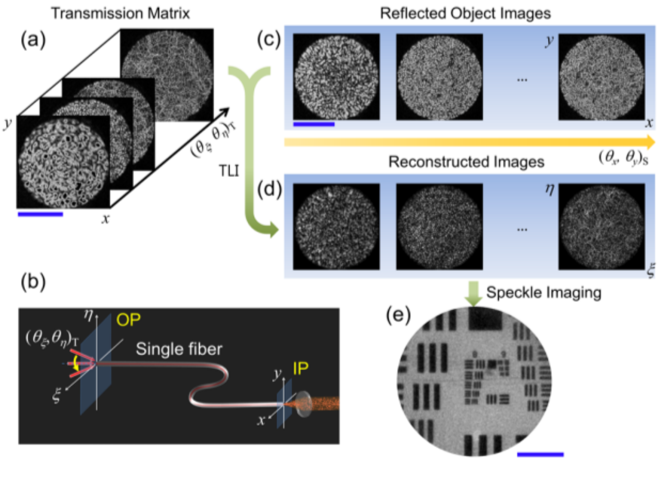
Current flexible fibre image guides that are used in endoscopes have a low resolution and a large cross section, since each fibre carries only one pixel of the image and has a diameter of 10 optical wavelengths. When light propagates in a multimode fibre there are many different propagation modes within the fibre, and the intensity of each of these can be said to carry one mode of image information. The interference of the light in these different modes can be observed as a 'speckle pattern' and by analysing the intensity distribution of this pattern it is theoretically possible to reconstruct the object. In this case, the number of available modes within the fibre image guide is approximately the cross sectional area of the fibre divided by the wavelength squared. It has been demonstrated that this approach can allow high resolution images to be transmitted through a single fibre [1].

Skeleton project plan

This project aims to develop real-time imaging and data processing algorithms and codes for a miniaturized fibre-optic imaging and sensing probe. There will also be the opportunity to work on optical experiments to record the speckle images. This is a highly multidisciplinary project based on a collaboration between Imperial College and University of Liverpool. Some trips to Liverpool may be required during the project.

Hardware/software requirements

- Matlab/C++
- Laser, fibre, camera and other optics.



[1] Choi et al. PRL 109, 203901 (2012)

Individual project 7: Development of a simulation environment for a novel cable-driven parallel bimanual robot for single access surgery

Supervisors: Dr George Mylonas, Dr Valentina Vitiello

Aims and objectives

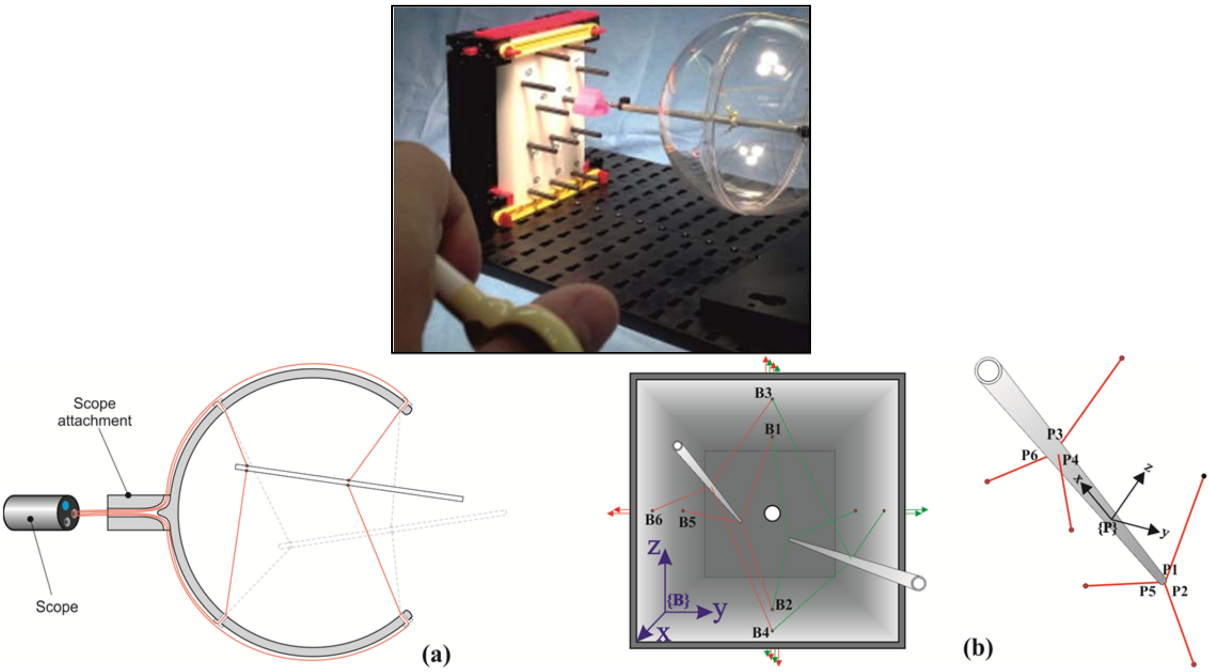
The purpose of this project is to develop a simulation framework for the analysis, control and validation of a novel cable-driven parallel bimanual robot for single access surgery.

Background

The CYCLOPS is a novel robotic tool for single-access surgery currently under development at the Hamlyn Centre. Its highly original design based on the concept of tendon-driven parallel robots, gives the system some of its unique capabilities, such as small size, unparalleled force exertion, large and adjustable workspace and bimanual instrument triangulation.

Skeleton project plan

The main focus of the project will be on the development of a virtual environment for the analysis, control and validation of the CYCLOPS design. Due to the nature of cable-driven parallel mechanisms, the kinematic model and workspace of the system are intimately related with its dynamics, which is in turn affected by the interaction with the environment. Force control becomes therefore critical to ensure the controllability of the platform. At the same time, the use of the manipulator for surgical task execution requires high positioning accuracy to guarantee the safety of the procedure. The control architecture will therefore need to take into account both force and positioning accuracy requirements. The user should also be able to manipulate the robotic instruments in a master-slave fashion, using a Phantom Omni haptic device as an input device. This also gives the potential to integrate haptic feedback during manipulation. Finally, the framework will be validated by designing a bimanual manipulation task and performing subject tests to assess the controllability of the system.



Key steps and milestones of the project include:

- Review of cable-driven parallel robots analysis and control techniques
- Kinematic modelling and workspace analysis of the CYCLOPS
- Master-slave control algorithm including force and positioning requirements
- Development of a simulation framework for the CYCLOPS
- Design of a bimanual manipulation task
- Validation of the framework through subject tests
- Framework porting to actual hardware (if time allows)

Hardware/software requirements

- Matlab/LabView/C++
- OpenGL desirable
- Phantom Omni
- CYCLOPS (at final stages and if time allows)

Individual project 8: 3D wearable eye-tracking for workflow segmentation, automation and collaboration in the surgical theatre

Supervisors: Dr George Mylonas

Aims and objectives

The aim of this project is to implement accurate 3D eye-tracking capability in the operating theatre with the use of a wearable monocular eye-tracker and one or more Kinect cameras. The 3D fixation information can then be used for segmentation of surgical workflow, theatre automation and for facilitating communication and collaboration between theatre attendants.

Background:

Information on visual attention and visual cues of collaborating participants or interlocutors, can facilitate disambiguation during the performance of a task and conversation. This information can also be of value in identifying episodes during a specific task. Clinical settings are particularly complicated but also intrinsically structured based on the requirements of a specific surgical operation. Knowledge on the occurrence of key “surgemes” (surgical phonemes) can help unravelling information on the underlying task based on visual attention alone.

Eye tracking can provide a measure of visual attention. However, monocular wearable eye-trackers can only provide a measure of gaze direction and 2D fixation information can subsequently be calculated based on a user specific calibration procedure. The resolved calibration parameters are only valid on a plane at a fixed distance from the user and correspond to the 2D fixation point on the eye tracking's scene-camera frame-of-reference. By using one or more Kinect cameras, it is possible to obtain a live 3D map of the surgical environment. At the same time, the eye-tracker scene-camera captures 2D images of the theatre whose appearance depends on the user's head pose. By tracking salient features on the eye-tracking image and by correlating them to the corresponding features of the Kinect cameras, it is possible to obtain a measure of the user's head pose in 6DoF. This information can then be used to map 2D fixations from the eye-tracking camera frame to 3D fixations on the Kinect frame, i.e., to the 3D space in the surgical theatre.

Key steps and milestones of the project include:

- Cross-correlation of salient image features between static eye-tracking camera and Kinect frames
- Pose estimation based on methods such as EPnP for estimation of the pose of a calibrated camera from n 3D-to-2D point correspondences
- 2D->3D fixation mapping
- Eye-tracking and Kinect systems integration
- User study (to be decided)

- Real time framework (if time allows)

Hardware/software requirements

- General computer vision knowledge
- Matlab, C/C++
- Kinect programming experience a plus but not absolutely necessary

Project number 9: Machine Learning and Modelling for Breast and Tumour Volume Measurement

Supervisors: Su-Lin Lee and Daniel Leff

Aims and objectives

A shape instantiation method will be developed to determine the complete 3D surfaces and volumes of the breast and tumour(s) using a trained model from pre-operative magnetic resonance (MR) imaging and limited mammography data. The end result will be an application allowing for the processing of further mammography data, providing surgeons with an indication of which treatment approach would be best suitable for patients.

Background

Standard breast conservation surgery (BCS) involves removing the breast lump with remodelling of the breast gland to achieve acceptable cosmesis. When the tumour and likely resection volume is estimated to be >20% of breast volume standard BCS is known to lead to poor cosmetic outcomes and surgeons prefer to use either oncoplastic techniques or mastectomy with or without reconstruction. The problem is that estimates of likely tumour-resection volume to breast volume are currently arbitrary and subjective; there is a risk of employing standard BCS in patient who would have required an oncoplastic technique (hence poor cosmesis) or conversely would have undergone an oncoplastic technique (increasing complexity) when a standard BCS procedure would have sufficed. Objective methods are more likely to lead to informed decisions about which procedure to employ when confronted with a breast cancer patient.

Currently, all patients undergo mammography (usually in both the craniocaudal and mediolateral oblique views), the majority of patients undergo ultrasound imaging, and some patients get a full volumetric MR scan. Volumes measured using MR scans are considered more accurate than the approximations obtained from mammography but measurement involves clinical time for segmentation. The project aims to determine a relationship between the measures that can be obtained from mammography and the complete 3D surface and volume of the breast and tumour(s) obtained from MR. By training on existing data, clinicians should then be able to obtain measures from mammography data from new patients and instantiate the full 3D data of their breast and tumour(s), thus obtaining a more objective ratio of tumour-resection volume to breast volume that will lead to better treatment options.

Skeleton project plan

- Literature review of the state-of-the-art in breast and tumour volume measurement;
- Breast and tumour volume measurement in MRI;
- Breast and tumour segmentation in mammography;
- Investigate machine learning techniques to derive shape instantiation from limited mammography data to complete volume measurements;
- Validation of the proposed method on existing retrospective data.

Hardware/software requirements

- MATLAB or C++

Project number 10: Vessel Retargeting with Intravascular Ultrasound

Supervisors: Su-Lin Lee

Aims and objectives

To develop a novel framework to assist clinicians with vessel retargeting using IVUS (intravascular ultrasound) imaging. The method developed will allow clinicians to identify areas of interest in a pullback sequence of IVUS images and then retarget (i.e. revisit) those regions with the IVUS catheter.

Background

IVUS is used to visualise the endothelium of blood vessels and can provide an indication of the composition of any blockage in the arteries. During an endovascular procedure guided by X-ray fluoroscopy, a pullback sequence (whereby the IVUS catheter is inserted into the vessel and then pulled back slowly while all the images acquired are recorded) is performed, providing clinicians with an information 'map' of the vessel and any blockages, allowing them to measure the stage and severity of disease. However, after a pullback of the IVUS catheter, clinicians find it challenging to return the catheter to an area of interest flagged in the IVUS pullback data. Areas of interest may include plaque deposits, vessel bifurcations, aneurysms, stenoses, etc; in general, these would be regions that require revisiting (e.g. to investigate further) or treatment (e.g. location for ballooning, stent graft placement, etc.).

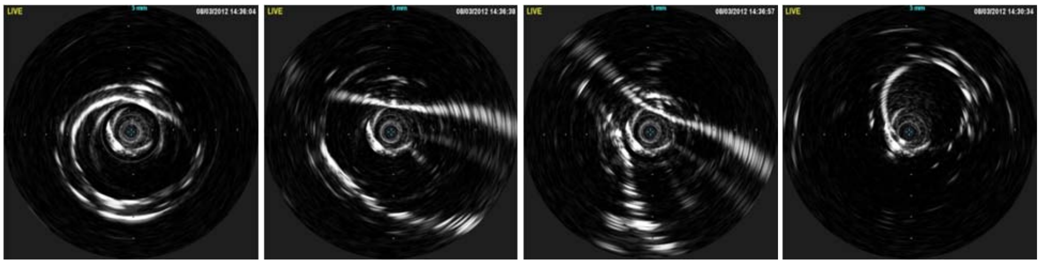


Figure 1*: Example IVUS images in a silicone phantom.*

The project will attempt to solve this clinical need in the area of endovascular intervention and the resulting framework will be a major step towards further application of IVUS imaging intra-operatively, including navigation, more accurate stent graft positioning, and live 3D vessel mapping. By depending on IVUS over X-ray fluoroscopy, the radiation dose to both patient and clinician is also reduced.

Skeleton project plan

- Literature review of the state-of-the-art in IVUS analysis;
- IVUS pullback sequences gathered in a silicone phantom that can be modified to include, for example, plaque deposits;
- Segmentation and feature detection in IVUS images to characterise the lumen of the vessels and identify areas of interest;
- A feature matching or other suitable approach developed to aid with vessel retargeting;
- Validation of the method by:

    - Attaching an electromagnetic tracking device to the tip of the catheter
    - Or obtaining full 3D information of the catheter and phantom using a CT scanner.

Hardware/software requirements

- MATLAB or C++
- IVUS catheter and scanner
- IVUS catheter pullback device
- Silicone aorta phantom
- NDI Aurora or Fluoro-CT scanner

Project number 11: Statistical Shape and Motion Modelling of the Aorta

Supervisors Su-Lin Lee

Aims and objectives

To develop a statistical shape and motion model of the aorta to assist with intra-operative endovascular guidance. The project will first require the building of a dynamic phantom that will be used for data collection and validation. Challenges include determining point correspondence across the 3D aorta surfaces and using shape instantiation to synchronise the model to the intra-operative imaging data, resulting in a dynamic 3D view of the vasculature that will provide clinicians with improved navigation through these complex procedures.

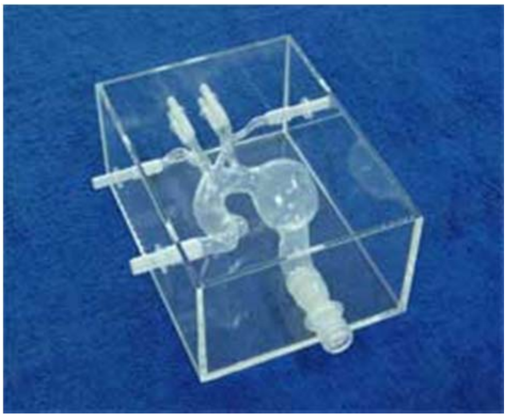


Figure 1: *An example of our silicone aortic phantom.*

Background

Current endovascular intervention depends on X-ray fluoroscopy for the manual and robotic guidance of guidewires and catheters. This exposes both patient and clinician to ionising radiation and only provides a 2D projection of the 3D structures. Soft tissue contrast is poor in X-ray images and it can be difficult to visualise the location of major vessels without the use of an iodine-based contrast agent. Due to the nephrotoxicity of the agent, it can only be used a limited number of times during a procedure. To improve visualisation of the vessels under X-ray, the use of 3D roadmaps has been introduced clinically; each roadmap is created by overlaying the 3D geometry of the vessels, obtained by pre-operative magnetic resonance imaging or intra-operative CT angiography, onto the live fluoroscopy. However, the volumetric scan is only obtained at one point in time and does not reflect the motion that the vessels undergo intra-operatively, either due to the cardiac or respiratory cycles.

The need for complete shape and motion modelling of the vessels on a subject-specific level, to guide the surgeon or interventional radiologist during an endovascular procedure, is clear. This would provide a dynamic 3D view of the vasculature intra-operatively, allowing for more efficient catheter manipulations, reducing the risk of errors in navigation and preventing collision of the catheter with the vessel walls.

Skeleton project plan

- Literature review of the state-of-the-art in vascular motion modelling;
- Develop a device to make our currently static silicone aorta phantom to be dynamic, using Lego Mindstorms;
- CT scanning the dynamic phantom to obtain 3D geometry of the aorta at different dynamic positions;
- Statistical shape and motion model built from the training set of dynamic aorta shapes;

- Shape instantiation of the entire 3D shape using a limited amount of intra-operative information.
- Demonstration of shape and motion model on recorded fluoroscopy data.

Hardware/software requirements

- MATLAB or C++
- Lego Mindstorms
- Silicone aorta phantom
- Fluoro-CT scanner

Individual project 12: Virtual NOTES Simulator - Tissue Modelling

Supervisors: Dr Fernando Bello and Mr Mikael Sodergreen

Aims and objectives

This project aims to incorporate tissue modelling to our existing NOTES medical simulator prototype, in order to model the interaction between flexible instruments used in NOTES surgery and tissue.

Background

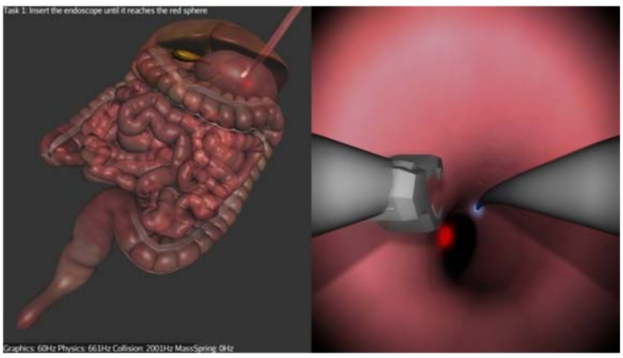
NOTES, Natural Orifice Transluminal Endoscopic Surgery, is an experimental surgical technique whereby "scarless" abdominal operations can be performed with an endoscope passed through a natural orifice, then through an internal incision in the stomach, vagina, bladder or colon, thus avoiding any external incisions or scars. A key aspect of this technique is the use of sophisticated flexible endoscopes and instruments. Very little work has been done so far in training for this new type of surgical interventions.

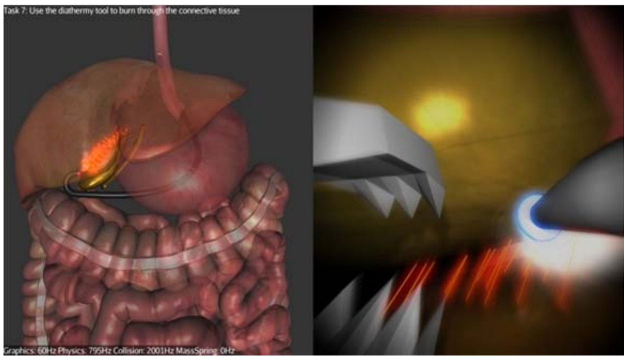
Skeleton project plan

The interactions (collisions, grasping, retracting, cutting) between the organs tissue and the flexible tools will be the focus of this project. The student will begin by familiarising her/himself with NOTES surgery and deformable models of soft tissue (mass-spring, finite element), as well as with the existing NOTES simulator framework. S/he will then investigate the suitability of various soft tissue models, testing and comparing their performance within the existing simulator. Once a model is chosen, the student will concentrate in optimising collision detection and collision response.

Hardware/software requirements

Programming may be done using C++, C# or Java and OpenGL (or any higher level graphics engine such as OGRE, JME3, Unity3D). Massively parallel implementations using CUDA or OpenCL will be explored. Previous experience in computer graphics and/or CUDA programming is desirable but not essential. The existing simulator is integrated with a haptic device to guide the endoscope and to generate adequate force feedback.





Individual project 13: Orthopaedic Surgery Simulation – Haptic Drilling

Supervisors: Dr Fernando Bello and Dr Alastair Barrow

Aims and objectives

This project aims to extend our basic prototype simulator in order to experiment with more realistic models of drilling and tool/tissue interaction, different surgical procedures, and additional computer aided learning techniques.

Background

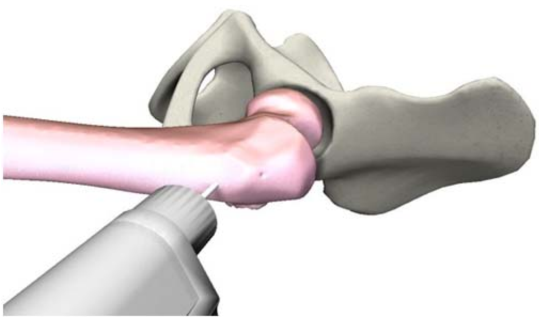
Haptic (sense of touch/force feedback) simulation is a powerful tool in surgical training, allowing users to experience the touch sensations arising in surgical procedures in a manner ranging from subtle, guiding forces, to highly realistic haptic rendering. The use of haptics in orthopaedic simulation is still relatively rare, more commonly research and commercial surgical simulation concentrates on soft tissues. A prototype haptic simulator has been developed to train the accurate placement of the initial pilot hole during a Dynamic Hip Screw (DHS) operation. The challenge in this kind of operation is that the accuracy of the hole is very important, but the procedure is largely "unsighted" and the surgeon must rely on X-ray images to verify correct positioning. Inexperienced surgeons will require many more X-rays to be taken and may need multiple attempts to drill the hole, putting the patient at risk. Therefore, a simulated training system is a valuable tool in this instance. However, this prototype simulator can be advanced and improved in many ways and the simulation technology itself can be applied to other kinds of orthopaedic simulation.

Skeleton project plan

The student will begin by familiarising her/himself with DHS and orthopaedic procedures generally, and with haptic simulation technology. S/he will then identify a new orthopaedic operation to be simulated and identify which aspects of the procedure may benefit from haptic technology. Once selected, the student will then begin by taking the existing simulation platform and adjusting the models and physical simulation characteristics to match the new procedure. As the project develops, the student will research new real-time simulation techniques to extend the simulator, adding new functionality and improving realism.

Hardware/software requirements

Programming/development will ideally be done using C++ and OpenGL. Previous experience in computer graphics / graphics programming is desirable but not essential, as is an understanding of mathematics for mechanics and 3D environments.



Individual project 14: Increased Immersion and Presence in Clinical simulation

Supervisors: Dr Fernando Bello, Dr Alastair Barrow and Dr Harry Brenton

Aims and objectives

This project aims to explore the use of the next generation of Head Mounted Displays (HMD) and other sensory feedback technologies to increase the level of immersion and presence in clinical simulation.

Background

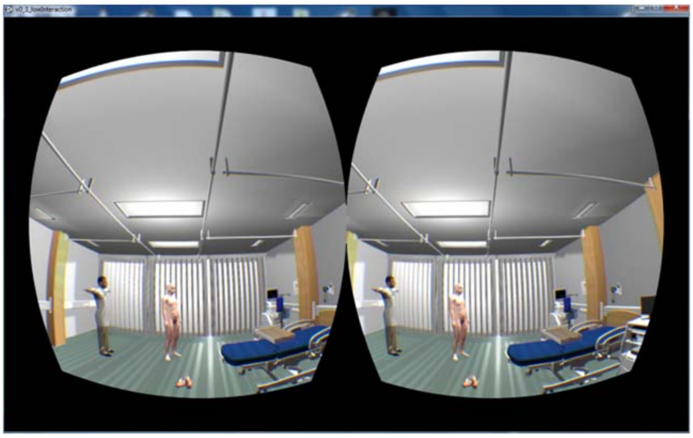
The concepts of presence and immersion in Virtual Reality (VR) are used to measure and compare objective and subjective levels of how much a subject feels part of a simulation. There is good e vidence to suggest that increased levels of immersion and presence in VR have numerous benefits related to learning a task or to becoming used to a particular environment or scenario. We are presently trialling a new generation of lighter, better quality and resolution HMDs, namely the Oculus Rift (www.oculusvr.com/), which shows promise for some clinical training applications. At the same time, we are continuously trialling new haptic devices and other sensory feedback technologies.

Skeleton project plan

The student will begin by familiarising her/himself with the Oculus Rift and other sensory feedback technologies (haptics, directional headphones, etc.), measures of presence and immersion and existing applications in clinical simulation. Following this, they will design and implement a virtual environment of a simple clinical scenario or task which can be experienced through using both highly immersive interfaces (e.g. Oculus rift with haptics and headphones giving directional sound) and a simpler, desktop interface which still allows the same task to be performed, but in a less immersive way. Once a functional simulation has been achieved, the researcher will conduct studies to assess the advantages of the different immersion technologies and the attitudes to the different simulation approaches, with particular emphasis on HMDs.

Hardware/software requirements

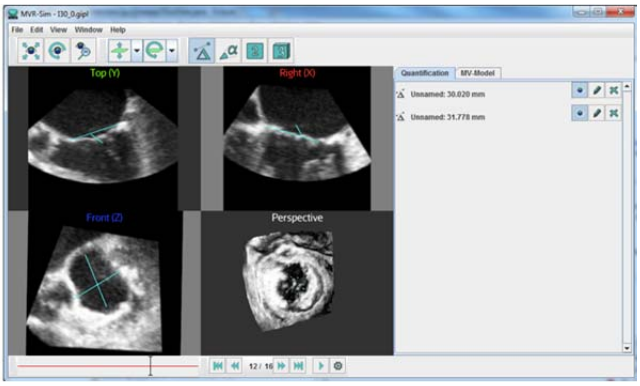
Previous experience in computer graphics / graphics programming is desirable but not essential. Programming/development using the Unity game engine (unity3d.com) will be encouraged, but it may also be done using C++ and a mainstream simulation development package such as OGRE.



Individual project 15: Computer-Assisted Surgical Planning for Mitral Valve Repair using 4D Echocardiograms

Supervisors: Dr Fernando Bello and Prof Gianni Angelini

Aims and objectives



This project aims to further develop our *MiVaR* (Mitral Valve Repair) simulator software by improving the current virtual valve model, simulator functionality and user interactions. Validation studies of the software being used to facilitate patient specific, computer assisted surgery planning for mitral valve repair will also be conducted in close partnership with our clinical collaborators.

Background

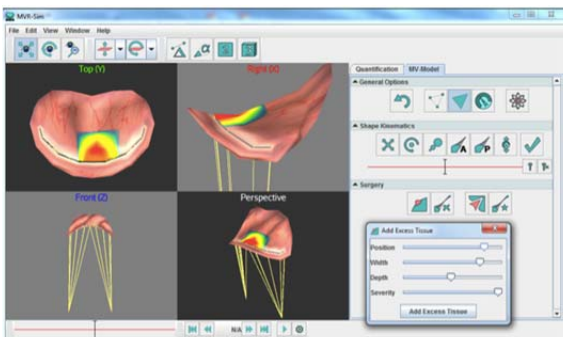
The mitral valve can become diseased, preventing it from adequately controlling the direction of the blood flow between the left atrium and left ventricle. It also can become insufficient (regurgitant), letting blood flow backwards into the left atrium (upper chamber) from the left ventricle (lower chamber) during ventricular contraction (systole). The mitral valve also can become stenotic (narrowed), preventing the flow of blood from the left atrium into the left ventricle during ventricular filling (diastole). In mitral valve prolapse, one or more of the mitral valve's cusps protrude back into the left atrium during ventricular contraction. Mitral valve repair is performed to improve the function of the diseased valve so that it correctly controls the direction of blood flow.

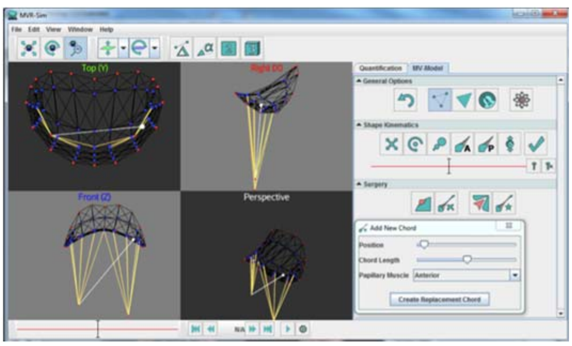
Skeleton project plan

Working with our clinical collaborators, the student will first gain an understanding of the clinical background to mitral valve repair, including 4D echocardiography. At the same time, s/he will become familiar with the current version of the MiVaR software and the underlying valve model. S/he will then explore several improvements to the virtual model and simulation such as additional tools to induce abnormalities, more accurate tissue surface representation, automatic model generation from echocardiograms, modelling of the coaptation surface and more realistic simulation. As the project progresses, the use and application of the improved MiVaR software for surgical planning will be evaluated.

Hardware/software requirements

Programming/development will ideally be done in Java and the JMonkeyEngine. Previous experience in computer graphics / graphics programming is desirable but not essential, as is an understanding of real-time soft tissue modelling.





Individual project 16: Spectrally Encoded Endoscopy using a Fibre Image Guide

Supervisors: Dr Daniel Elson

Aims and objectives

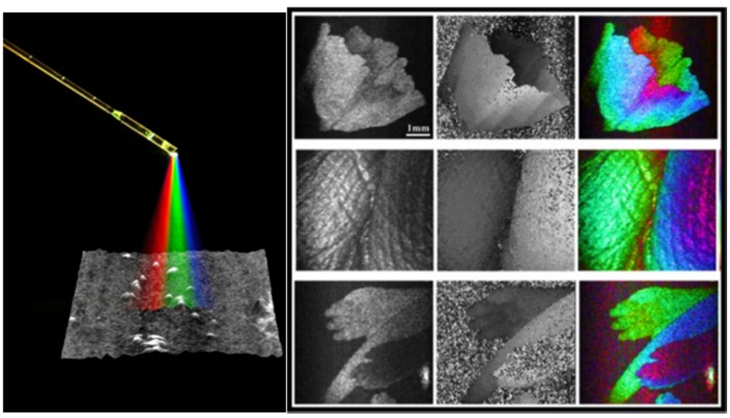
A new type of ultrathin imaging endoscope probe will be developed that achieves high spatial resolution.

Background

Thin endoscopic probes typically use fibre image guides to transmit images, although as the diameter shrinks the number of fibres, and hence the resolution, decrease. Spectrally Encoded Endoscopy (SEE) is an approach that has been developed by a team at Harvard to allow images to be acquired through a single optical fibre by dispersing the light into its constituent colours on the tissue surface. By recording the spectrum of the reflected light, the reflectivity of different parts of the sample can be distinguished and used to reconstruct a one-dimensional image of the tissue. There are also various approaches to make this technique into a two-dimensional colour imaging method. In this project a new high resolution method of SEE will be developed that uses a small diameter fibre bundle together with an imaging spectrometer.

Skeleton project plan

This project involves design, build and test phases and will lead to the demonstration of a new prototype endoscope. A fibre bundle will have a circular cross-section at the distil tip and a line profile at proximal tip, which will be aligned with the input slit of an imaging spectrometer. This device will allow the spectrum to be acquired from every fibre in the bundle. Optics will be designed and attached to the distil tip to disperse the light from each fibre onto a separate region of the tissue. The resolution of the endoscope will therefore be increased to the number of fibres multiplied by the number of distinct spectral channels. These parameters will be explored in a design process before the items are procured and the system built and tested.



OPTICS LETTERS Volume: 27 Issue: 6

Hardware/software requirements

A design/build/test project involving use of simulation tools and hardware skills. All optics and consumables will be provided by the biophotonics laboratory.

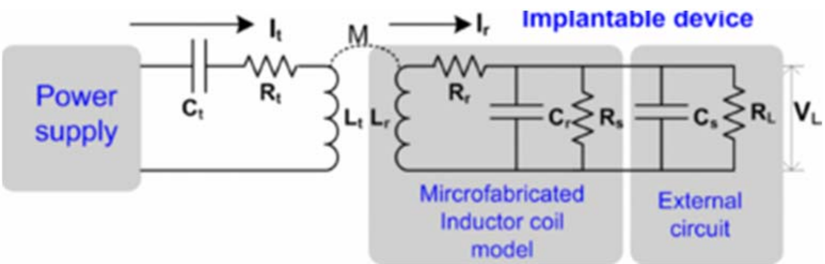
Individual project 17: Magnetically anchored oesophageal pH sensing

Supervisors: Dr. Pádraig Cantillon-Murphy, Dr. Benny Lo, Prof. Guang-Zhong Yang

Aims and objectives

The overall objective of this project is to design and develop a magnetic anchoring system for short-term attachment of an implantable pH sensor to the patient's oesophageal wall. The system will comprise in two coupled conductive coils, one external and the second one anchored to the oesophageal wall. This final objective will comprise four sequential aims:

a) Design and implement two planar electromagnets which are; (1) capable of magnetically coupling at separation distances up to 3-4cm, and (2) are suitably scaled for endoscopic deployment (internal coil). In this initial aim, both electromagnets are independently powered from DC sources.
b) Integration of the internal coil and control circuitry with the pH sensor circuit. It is intended that the internal system will intermittently transmit pH data by inductive coupling to the external coil in the kHz range (AC transmission).
c) Design and implementation of resonant wireless power transfer to the internal coil by (AC) inductive coupling such that the internal coil and pH sensing circuitry does not rely on any internally implanted battery or power source but is powered entirely from the external circuit.
d) The final aim is to test and evaluate the system performance in a meaningful pre-clinical setting.



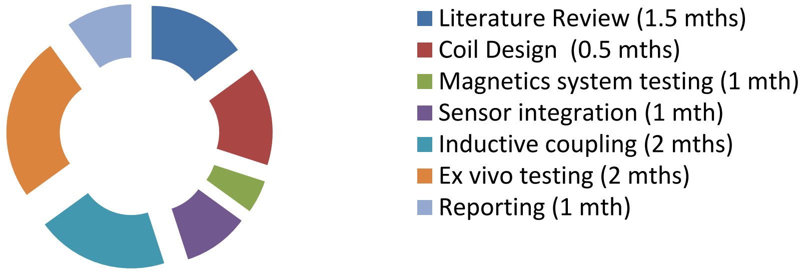
An example of wireless inductive power transfer for transcranial applications[1]. Example of Barrett's oesophagus

Background

Oesophageal disorders such as Barrett's oesophagus are closely correlated with pH abnormalities due to chronic acid exposure in the oesophagus[2]. Barrett's patients are at increased risk of a range of cancers[3,4] and the condition is just one of a number of gastrointestinal disorders where patients might benefit from time-averaged (e.g., 24 hour) monitoring of pH. Magnetic anchoring presents a significant advantage over current capsule monitoring since the pH sensor can be anchored statically using the proposed approach.

[1] N Xue et al., 2012 J. Micromech. Microeng. 22 075008. doi:10.1088/0960-1317/22/7/075008
[2] CS Neumann et al., 2003 Gut 52(1): 153–154.
[3] F Hvid-Jensen et al., Gastroenterology. 2011 Gastroenterology 140(3): e18–e13.
[4] D Theodorou et al., J Gastrointest Surg. 2012 16(3): 469-474

Skeleton Project Plan



Hardware/software requirements

Circuit design software ● *PSpice* or similar ● *Matlab* software ● Circuit prototyping

Individual project 18: Multimodal spectroscopy for monitoring tissue changes during RF heating

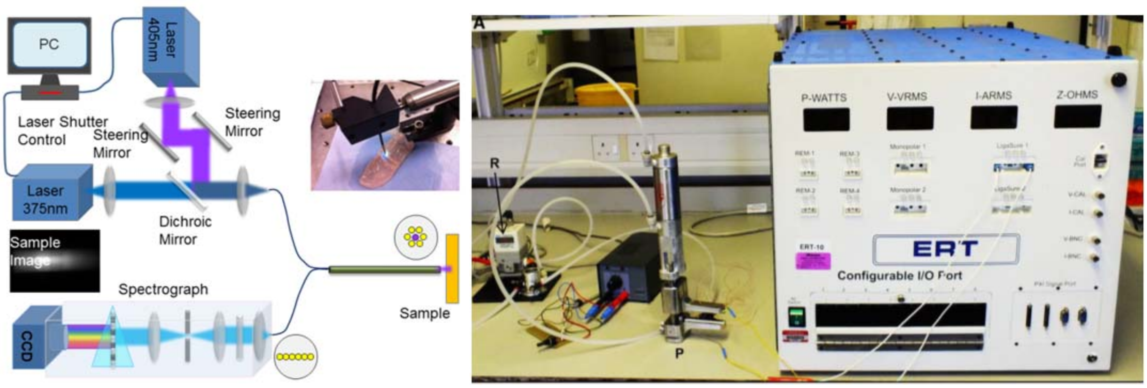
Supervisors: Professor George Hanna, Vadzim Chalau, Dr Daniel Elson, Dr Bruce Dunne (Covidien Inc.)

Aims and objectives

- To build an instrument that can detect the fluorescence and diffuse reflection spectra during tissue heating and fusion
- To integrate the probe into the jaws of a device used for tissue fusion
- To record data in vivo during bowel anastomosis.

Background

We are investigating the fusion of colon tissue by using RF energy in a project supported by Covidien. Previously we have used fluorescence and Rama spectroscopy to detect tissue biochemical and morphological changes pre and post fusion. We now wish to construct a fibre probe system that can be incorporated into the jaws of the tissue fusion device during the procedure.



An example spectroscopy system and the 'ERT' – Covidien's tissue fusion research tool.

Skeleton project plan

The probe will be designed so that both fluorescence and reflectance data can be acquired simultaneously and in real-time. The signals will be analysed for correlations between the optical signal and the electrical impedance and outcome of the anastomosis. Animal trials have already begun and will continue throughout this project, with the final device used to predict whether the tissue is fully fused.

Hardware/software requirements

- Various optics and optomechanical parts
- Spectrometers and light sources
- LabVIEW
- Matlab

Arya et al. Surg. End. (2013) DOI 10.1007

Su et al. Journal of Biophotonics (2013)

Individual project 19: User-safe Robotic Arm

Supervisors: Ching-Mei Chen, Jindong Liu and Benny Lo

Aims and Objectives

Development of a user-safe robotic arm for healthcare mobile robots

Background

One of the major obstacles in widespread use of mobile robots for assistive living is the safety concerns on the robots, especially in the use of robot arms during human-robot interactions. However, robot arms are essential components for assessing users' health in an assistive living application. To safely perform health assessment, mobile robots have to integrate with intelligently control robot arms to guarantee the user safety during the physical human-robot interactions. Intelligent sensing and motor control are two of the key factors. At present, none of the self-sustained arm unit is compliant to physical user interaction. A light weight, user compliant and high performance robot arm is demanded to build. Given the availability of existing FPGA/ARM development kit, robot arms and physiological sensors in our lab, it is feasible to apply such methods to develop a practical system.

The controller is expected to be a self-sustained unit to integrate closed-loop position control, user compliant control, safety diagnoses and host communication within the robot arm (Figure 1). The controller will be based on a customised robot arm which is equipped with accelerometers for each joint. The control system will be based on a FPGA motor control development kit and a customised motor drive board. Several measurable objectives are stated as follows: (i) to design a FPGA/ARM motor control system; ii) to design a miniature torque/force sensor to sense the force applied on end-effector from human; iii) to detect user physical interact with the arm by integrating accelerometers and torque sensors; iv) to implement user compliant control to avoid the hurt to human; v) to evaluate the system regarding to user safety and control accuracy.

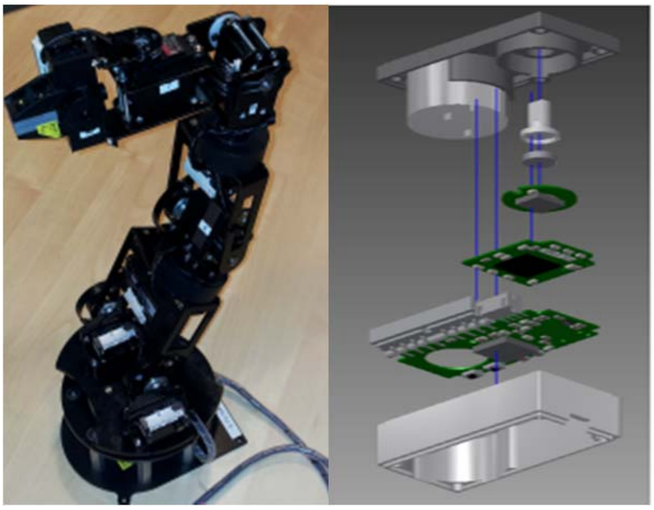


Figure 2: Robotic Arm and Hamlyn Motor Controller

Skeleton Project Plan

The project is expected to be implemented within six months with following tasks:

1. Implement PID-based position control of the DC motors by using a FPGA/ARM development kit
2. Design a torque sensor using strain gauge sensors
3. Detecting physical interaction using accelerometers and torque sensors
4. Implement user compliant motor control by integrating position control and physical interaction detection
5. Testing performance of robot arms
6. Thesis writing

Hardware / Software Requirement

- FPGA/ARM Motor Control Development Kit
- The customised Cyton Alpha 7D Robotic Arm
- Torque sensor (Nano 17 as reference), current sensor, motor encoders and temperature sensor
- IC components for motor drive board
- Xilinx ISE® Design Suite (Licence included in Xilinx hardware purchase)

Individual project 20: Patient Vital Sign Sensing using a Robotic Arm with Bio-signal Sensors

Supervisors: Jindong Liu, Ching-Mei Chen and Benny Lo

Aims and Objectives

Developing an autonomous vital sign collection system using a robotic arm with bio-signal sensors

Background

Vital signs are measures of various physiological statistics, often taken by nurses, in order to assess the most basic body functions. Vital signs are an essential part of a health assessment. General vital signs include body temperature, pulse rate (or heart rate), blood pressure, and respiratory rate, etc. In the general ward, patients are visited every few hours to collect vital signs. This procedure takes hours of nurses' working time. To saving the time and simplify the procedure, a mobile robot with a robotic arm can be adapted to collect vital sign autonomously or semi-autonomously.

In this study, a robotic arm (shown in Figure 1) equipped with miniature bio-signal sensors is going to collect vital signs from fingers and foreheads for the patients in general wards. Heart rate and body temperature are chosen as the example of vital signs in this early stage. The measurable objectives are stated as follows: (i) detect and locate patient's hands and forehead using colour and depth camera; (2) to plan the trajectory of the end effector of the robotic arm to move to the desired parts of the patient body, this trajectory is adaptive to the subtle hand motion; (3) to attach the bio-signal sensor to the patient's finger or forehead, this task includes a simply mechanical device design; (4) to collect the vital signs via microcontroller or FPGA and conduct a real-time diagnosis onboard.

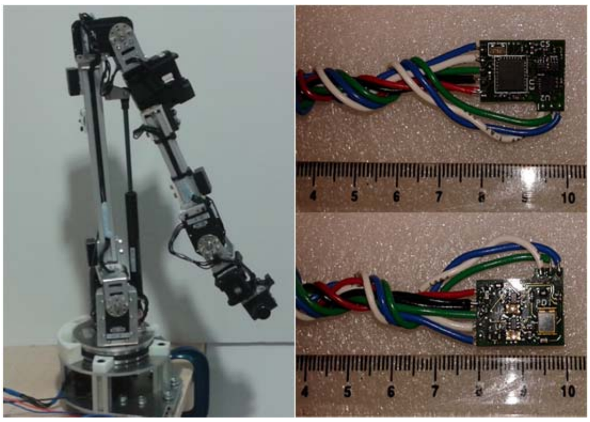


Figure 3: (Left) Robotic Arm, (Right) Bio-signal sensor

Skeleton Project Plan

The project is expected to be implemented within six months with following tasks:

1. Literature review on dynamic human-robot physical interaction
2. Human body detection and tracking using colour and depth camera, mainly forehead and fingers, for patients in bed.
3. Dynamic trajectory planning for a light-weight robotic arm, the planning should be adaptive to patient's subtle hand motion.

4. Design a mechanical mechanism to attach bio-signal sensor on patient’s fingers and forehead
5. Online signal processing for assess the vital sign and provide report to nurses.
6. Testing performance of robot arms and collect vital sign from simulated patients.
7. Thesis writing

Hardware / Software Requirement

- The Hamlyn Robotic Arm
- The Hamlyn Heart rate variability/Body temperature measurement sensors board
- Kinect colour-depth sensor
- Xilinx ISE® Design Suite (Licence included in Xilinx hardware purchase)

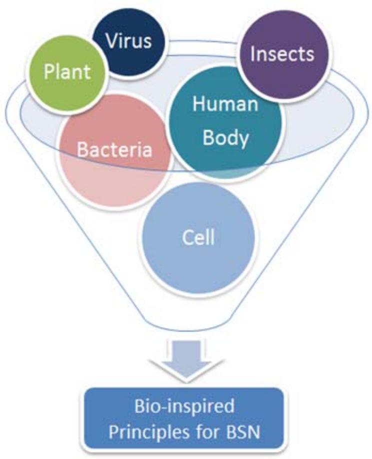
Individual project 21: Autonomic Body Sensor Networks

Supervisors: Benny Lo and Guang-Zhong Yang

Aims and objectives

Following the evolution of computers, the size of the computer is getting smaller and smaller, one has predicted that miniaturised sensors will soon overtake the mobile phones/computers to become the next generation of computers. There are growing interests in Wireless Sensor Networks (WSN), Internet of Things (IoT) and Body Sensor Networks (BSN). In particular, BSN focuses mainly on the application of miniaturised sensors for healthcare and wellbeing applications. Although sensor miniaturisation can greatly minimise the obtrusion to the user and improve usability and compliances, it greatly limits the computational capacity of the sensors. With the growing number of sensors with very limited computation power, managing and configuring the sensor system could become a humanly impossible task. Adapting from the concept of Autonomic Computing, the concept of Autonomic Sensing was proposed, and the characteristic of an autonomic sensing system is described. An Autonomic Sensing system should be self-managed, self-configured, self-optimised, self-healed, self-protected, self-adapted, self-integrated, and self-scaled. In this project, an autonomic BSN system will be designed and developed with some of the autonomic sensing characteristics, such as self-configuration, self-healing and self-optimisation. To demonstrate the concept, use cases and scenarios will be designed based on an activity recognition application, and both wearable and ambient sensors will be integrated into the BSN system. In particular, a dynamic reconfigurable network infrastructure will be developed based on the BSN sensors. User studies will be designed and conducted to test and validate the network capabilities based on the designed scenarios. Self-configuration, self-healing and self-optimisation mechanisms will then be designed and developed using techniques, such as feature selection, network optimisation, noise-resilient sensing, distributed inferencing, etc., and novel approaches could be introduced to improve the robustness of the network. The autonomic system developed will be tested and validated based on the designed scenarios and use cases.

Acitivity recongition with both wearable and ambient sensors



Bio-inspired Body Sensor Networks

Background

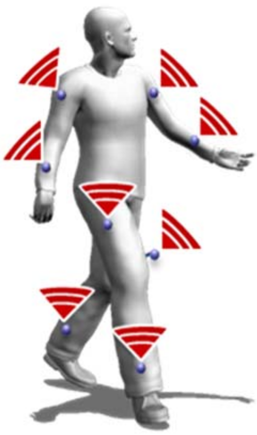
One of the main objectives of Body Sensor Networks (BSN) is to enable ubiquitous use of miniaturised wearable or implantable sensors to better patient care and improve wellbeing. Since its introduction, the BSN concept has facilitated the development of many innovative and pervasive sensing devices, and some of which have already demonstrated their clinical relevance and potentials in enhancing patient care. However, the ubiquitous use of miniaturised sensors would lead to major problems in system management, quality of service, security, and administration. The same problems are currently faced by the IT industry. To overcome the increasing demand, recent research has investigated in adapting biological mechanisms in managing the ever growing IT infrastructure. For instance, the biological immune system is probably the best defence system ever existed, and which has been tested and evolved through million years of evolution. The innate and adaptive capabilities of the immune system have protected living organisms against countless pathogens and toxic substances. It has inspired the development of numerous defence mechanisms for computers against malicious attacks. Although BSN systems will face similar problems, addressing the issues will be much more challenging due to the very limited resource of the sensors, the vast volume of data generated by continuous sensing, and the highly sensitive patient information handled by the systems. Based on the experiences and concepts applied in the IT industries, a number of bio-inspired concepts have been proposed for BSN applications, in particular, adapting autonomic mechanisms in managing large-scale BSN sensing systems. In this project, some autonomic sensing algorithms, such as self-configuration, self-healing and self-optimisation will be developed for BSN applications.

Skeleton project plan

Tasks	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Literature review								
Design scenarios and use cases								
Network architecture design and development								
Test and validate the network architecture								
Develop self-configuration and self-optimisation mechanisms								
Develop self-healing approach								
System test and validation based on the uses cases								
Writing up the thesis								

Hardware/software requirements

- BSN sensors
- Ambient sensors
- BSN OS
- Matlab
- Sensor programming software (IAR Workbench)



Individual project 22: Diffusion Tensor and Myocardial Contractility Analysis with Cardiac MRI

Supervisors: Robert Merrifield, Professor Guang-Zhong Yang

Aims and objectives

Develop a versatile diffusion tensor and myocardial contractility analysis platform based on cardiac MRI.

Background

Cardiac MR is an important clinical tool for the management of cardiovascular disease because of its safety and versatility. Current techniques being developed include real-time adaptive imaging for capturing detailed anatomical abnormalities, integrated/targeted multi-spectral imaging for linking function with morphology and tissue composition for targeted assessment of cardiovascular structure and function, and novel techniques such as MR perfusion and diffusion imaging sequences that enable early assessment of the functional integrity of heart. Diffusion tensor MRI is a relatively new technique for measuring anisotropic diffusion properties of the myocardium, thus enabling the visualisation of fibre-orientation and sequential changes of myocardial microstructure in patients after myocardial infarction.

Skeleton project plan

The project will be carried out in collaboration with the Royal Brompton Hospital. The candidate needs have a strong background in mathematics (particularly in solving PDE) and to be proficient in programming and interactive 3D visualisation. Key steps and milestones of the project include:

- MR diffusion tensor and velocity imaging and sequence optimisation;
- PDE based tensor field restoration and data quality improvement;
- Tensor data interpolation and resolution enhancement;
- Fibre tracking with dynamic regularisation;
- Interactive 3D visualisation and user interface design and development;
- In vivo validation and patient studies.

Hardware/software requirements

- Interventional CMR Suite and pulse programming environment
- C/C++ and OpenGL programming
- Matlab simulation

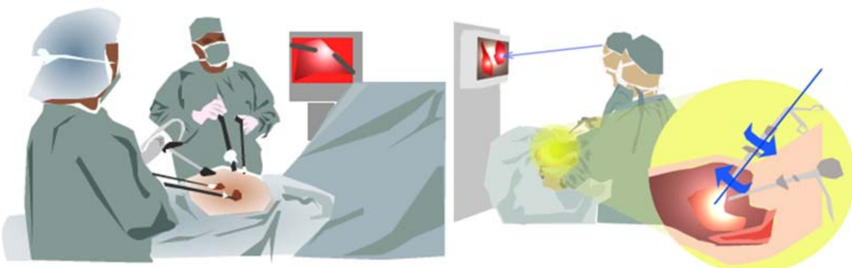
Individual project 23: Objective assessment of surgical dexterity with pervasive sensors

Supervisors: Benny Lo and Mikael Sodergren

Aims and objectives

With the advances in BSN and pervasive sensing technologies, increasing number of low-cost miniaturised sensing devices have been introduced for different applications. Recent studies have demonstrated the use of inertial sensors for capturing hand and finger movements for surgical skill assessments. The aim of this project is to develop a low-cost objective assessment tool based on pervasive sensors for Minimally Invasive Surgery (MIS) training. In particular, this project will initially focus on using miniaturised inertial sensors in capturing hand movements. A subset of surgical training procedures will first be selected. A wireless hand tracking system will then be designed and developed accordingly to quantify the parameters used to evaluate the quality of the procedures. A user study will be conducted using a standard box trainer together to test the system against a passive infrared optical tracking system. In addition to inertial sensors, the project will also investigate the incorporation of different sensing modalities, such as physiological sensors, laparoscopic video images and eye-tracker, for capturing the perceptual-motor, visual-spatial and cognitive factors in the surgical training procedures.

Expert and novice surgeons will be invited to participate in the studies, and the multimodal sensory data acquired will be used to formulate an objective scoring system. The scoring system will then be validated against standard surgical skill assessment tools, such as OSATS (Objective Structured Assessment of Technical Skill). In addition, to evaluate the functions and accuracy of the system, experiments will be conducted in Oxford, jointly with Alvand and Rees, where the developed system will be compared against their wired sensor system.



Minimally Invasive Surgery (left) and fulcrum effect (right)

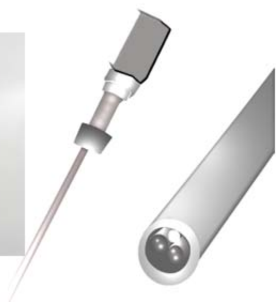
Background

Compare to conventional open surgery, Minimally Invasive Surgery (MIS) can greatly reduce patient trauma, shorten the recovery and minimises the risk of post-operative complications. However, MIS requires a high degree of manual dexterity from the operators due to the complex instrument controls, restricted vision and mobility, difficult hand-eye co-ordination, the fulcrum effect and the lack of tactile feedback. To alleviate these problems, MIS specific training is essential for the safe practice of these procedures. Thus far, the development of Virtual Reality (VR) simulators, such as the Minimally Invasive Surgical Trainer-Virtual Reality (MIST-VR), has been a major focus of research in surgical technology as they allow for comprehensive training of MIS specific surgical tasks. Despite the fact that simulators have advanced significantly in recent years, they are still not realistic enough to be taken as the only source of training, nor for the acquisition and assessment of certain advanced surgical skills. To facilitate objective assessment of surgical skills, much research has been conducted on developing different technologies to assess the perceptual-motor, visual-spatial, and cognitive factors involved in MIS, such as sensor equipped instruments, hand tracking, eye-tracking, near-infrared spectroscopy, instrument and tissue tracking, etc. However, due to the cost and complexity in setting up and configuring the proposed technologies, most of the approaches are limited to research studies and cannot be adopted to core surgical training programmes. With the advances in miniaturised pervasive sensors, this project aims to develop a low-cost and pervasive sensing system for objective assessment of surgical skill.

Skeleton project plan

Tasks	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Literature review								
Experiment design – identify surgical training procedures								
Hand tracking system design and development								
Ethics application								
User studies and system validation								
Assessing other sensing modalities and system integration								
Study with novice and expert surgeons								
Development of objective scoring systems								
System validation against standard scoring systems								
System validation (Oxford)								
Writing up the thesis								

Hardware/software requirements



- BSN sensors
- MatLab
- BTS tracking system and/or Optotrack
- A surgical Box trainer
- An laparoscopic camera
- USB video grabber
- Laparoscopic instruments, which includes graspers, scissors, dissectors, etc.
- Surgical training kit with sutures, needles, and imitation skin
- Eye tracking system

Collaborators

- The Hamlyn Centre, Imperial College London
- Oxford Medical School
- McLaren Applied Technologies

Individual project 24: Optical Sensing for Hand-held Tremor Compensation Robots

Supervisors: Christopher Payne and Professor Guang-Zhong Yang

Aims and objectives

Evaluation of real-time sensing strategies and development of a platform that will provide the input to a hand-held tremor compensation robot.

Background

Hand-held robots are an alternative to master-slave and cooperatively-controlled grounded robots that are affixed to a stationary reference frame [1]. They have the advantages of being compact, unobtrusive to manipulate, lower cost and can be seamlessly integrated in to the surgical workflow. Tremor compensation hand-held mechatronic devices work by sensing the tremor of the operating surgeon and servoing the surgical end-effector by an equal and opposite distance so as to effectively stabilise the tool tip [2]. A fundamental requirement in being able to achieve tremor compensation is the effective measurement of the surgeon's tremor at acquisition rates in the order of 1kHz. This is commonly achieved using inertial sensing [3] or optical tracking [4]. Optical tracking uses multiple position-sensitive devices (PSDs) for the localisation of multiple light emitting diodes (LEDs) that are attached to the hand-held device. Alternatively, inertial sensing and vision-based sensing [5] can be used to determine the absolute position of the instrument tip. The final goals of the project are to determine the optimal sensing input modality for hand-held tremor suppression devices and to deliver an optical tracking platform for integration with a hand-held device.

- Development of an optical tracking rig to facilitate 3D localisation of the hand-held instrument.
- Implementation of control algorithms for tremor suppression of a hand-held instrument using the investigated sensing strategies.
- Validation of the developed sensing strategies

Figure 1: Hand-held motion compensation device

Skeleton project plan

The candidate needs have a strong background in electrical/control engineering and to be proficient in building electrical and mechanical hardware. Specific steps and milestones of the project include:

- Review of sensing strategies for hand-held tremor suppression instruments
- Interfacing of PSDs and LEDs with a real-time system

- Development of a tracking rig
- 3D calibration and performance analysis
- Interfacing of inertial measurement units and vision-based tracking
- Evaluation of the optical tracking against inertial measurement/vision-based strategies

Skills and hardware/software requirements

- Proficiency in control engineering and real-time systems
- Electrical engineering hardware skills
- Labview or real-time Linux programming skills
- Ability to implement vision-based algorithms
- 3D rapid prototyping and mechanical assembly

References

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Individual project 25: A learning from demonstration framework for robotic-assisted minimally invasive surgery

Supervisors: Dr Valentina Vitiello and Professor Guang-Zhong Yang

Aims and objectives

The purpose of this project is to investigate novel methods for importing the surgeon's experience and knowledge into the performance of collaborative surgical tasks in robotic-assisted minimally invasive surgery. Building on an existing control framework developed by previous students, the aim is now to integrate two robotic manipulators for the execution of a bimanual surgical task.

Background

Learning from demonstration (LfD) techniques provide an intuitive and natural way to gain knowledge from subject-specific motor and perceptual behaviour *in situ*. The robotic system can collect information from surgeon demonstrated trajectories, defined as best practices, and extract knowledge of the demonstrated task in order to reproduce it in an autonomous way. Two KUKA lightweight robotic arms will be integrated in a platform for the cooperative execution of a bimanual surgical task. The compliance of the robot will firstly be exploited to perform kinaesthetic teaching *in situ*; consequently, the LfD framework will generate optimal task trajectories that can then be executed by the robot autonomously. In addition, external sensors will be used to provide the system with cognitive capabilities by extracting information from the surgical scenario.

Skeleton project plan

The main focus of the project will be on the extension of the already existing LfD framework to include two robotic manipulators in the surgical scenario. This requires exploiting the system redundancy and self-awareness as well as additional information from external sensors to achieve optimal workspace and task execution for both arms while ensuring safe interaction between the robots and the surgical environment. The complete LfD framework will finally be integrated in a robotic-assisted surgical procedure to achieve optimal bimanual task execution through cooperative control. Key steps and milestones of the project include:

- Review of LfD techniques and previous work
- Kinematic modelling and workspace analysis of KUKA lightweight robotic arm
- Extension of the existing LfD framework to include two robotic manipulators
- Integration of constraints and additional information from external sensors
- Experimental design of a robotic-assisted bimanual surgical task
- Integration of the complete LfD framework with the KUKA robots and experimental set-up
- Control of KUKA lightweight robotic arms for cooperative bimanual task execution

Hardware/software requirements

- KUKA lightweight robotic arm
- Tracking device (NDI Polaris Vicra and/or MS Kinect)
- ATI force/torque sensing system
- Fast Research Interface for KUKA Robot Control
- Matlab/LabView/C++/Linux Real-Time Kernel

Individual project 26: Robust Pattern Tracking for Ultrasound Guidance in Cancer Surgery

Supervisors: Dr Philip Pratt, Dr Christos Bergeles, Prof Guang-Zhong Yang

Background

The benefits offered by laparoscopic and robotic surgery are significant for patients: reduced chances of postoperative infection, small incisions resulting in less wound pain and shorter recovery times in hospital, and improved cosmetic results. However, these benefits come at a price to the surgeon. The sensory experience is compromised, in the sense that while monoscopic or stereoscopic vision is provided, the opportunity available in open surgery to palpate or 'touch' the target tumour and surrounding anatomy is taken away. It is therefore challenging to define the boundaries of the tumour, and therefore ensure that a complete resection is achieved. This project hopes to address this problem by providing real-time contemporaneous overlay of ultrasound imaging onto the surgeon's video feed of the operative scene. Sometimes referred to as augmented reality, this approach aims to enhance sensory input by allowing the surgeon to visualise structure beneath internal tissue and organ surfaces, that previously would have been examined with the sense of touch. Moreover, instead of a traditional ultrasound scan taken externally through the skin, a miniature linear array microsurgery probe is passed through one of the keyhole incisions and deployed directly on the tumour and target pathology.

Aims and objectives

The aim of this project is to enhance the existing ultrasound guidance platform such that the robustness of tracking is significantly improved. At present, the harsh lighting conditions, confined surgical workspaces, processing delay and instrument occlusions make the system quite challenging to use. Several approaches are possible, including the development of more sophisticated algorithms for pattern recognition and outlier detection, through to pose optimisation based on pixel-wise comparison of real and virtual scenes. The existing system has already been used in a number of human cases, e.g. transanal endoscopic microsurgery (see Figure 1), and robotic partial nephrectomy. This project therefore represents an exciting opportunity to translate successful developments into the operating theatre. Candidates will be expected to have strong C/C++ programming skills with, ideally, some knowledge of CUDA and parallel processing techniques.

Skeleton project plan

- Literature review
- Acquire human data sets from existing video database
- Install development tools and acquire existing source code and configuration files
- Learn and perform ultrasound probe calibration procedure
- Use human data and laboratory work to develop improvements to existing tracking algorithms
  Preparation of MRes thesis

Hardware/software requirements

- Aloka UST-533 microsurgery probe and ProSound Alpha-10 cart
- KeySurgical laser-etched tracking marker dots

- Mono and stereo endoscopes (Wolf telescope, in particular) with camera heads and controllers
- Portable workstation with video capture hardware and CUDA-enabled GPU
- Video processing and baseline feature-based pattern tracking software components

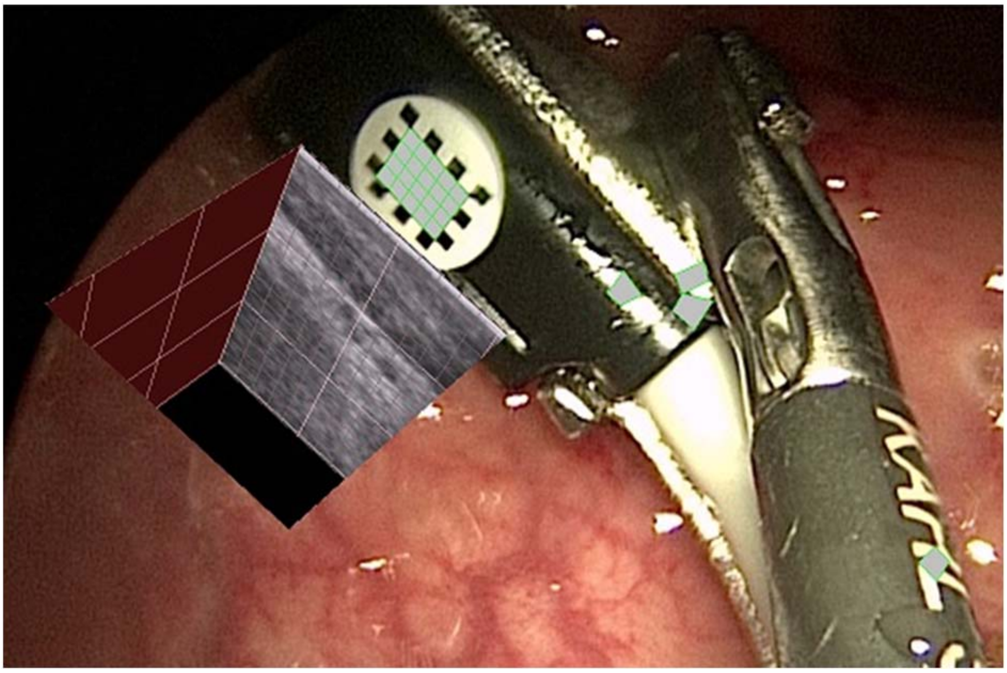


Figure 1. Footage from 01-Nov-2013 TEMS case illustrating ultrasound overlay with clear visualisation of tissue layers.

Individual project 27: Navigation and Tumor Margin Delineation in Cancer Surgery

Supervisors: Stamatia Giannarou, Tou Pin Chang, Guang-Zhong Yang

Aims and objectives

The aim of this project is to build a novel framework to assist surgical navigation and to map morphological and microscopic information for accurate delineation of tumour margins intra-operatively.

Background

With recent advances in medical imaging and surgical robotics, cancer surgery has entered a new era which is set to bring major healthcare and socio-economic benefits. Complete resection of tumours during surgery is crucial for improving survival rates and quality of life for the patient. Accurate delineation of tumour margins intra-operatively is a challenging task, making complete resection and clearance of surgical margins difficult. Pre-operative imaging modalities such as MRI are unable to account for geometrical changes in the anatomy due to the surgical intervention itself and their use intra-operatively is associated with significant cost.

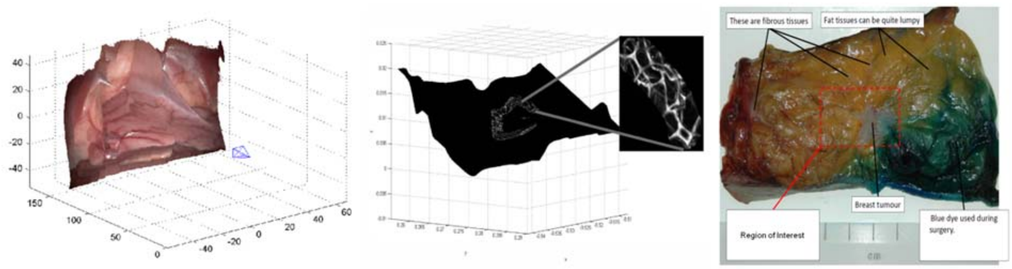
With recent advances in biophotonics and surgical instrumentation, it is possible to bring cellular and molecular imaging modalities to an in vivo, in situ setting to allow for real-time tissue characterization, functional assessment and surgical guidance. Confocal Laser Endomicroscopy (CLE) enables direct visualisation of the tissue at a microscopic and macroscopic level and can be used in combination with an endoscope, introducing an optical probe through the working channel to be placed in contact with the tissue to provide ‘optical biopsy’ without excision of tissue.

Surgical navigation and efficient tissue screening requires the recovery of dense 3D surface geometry and the subsequent augmentation of morphological and microscopic information. This is because probe-based endomicroscopy systems provide histological information for a very small, localised area of the tissue surface. Therefore, a live augmented visualisation of microscopic information on the endoscopic view in vivo would assist visual-aided navigation by facilitating the retargeting and serial examination of optical biopsy sites or potential pathological sites.

Brief project plan

Dense 3D scene reconstruction: Dense 3D reconstruction can be challenging due to the paucity of distinctive features, the presence of specular highlights and the narrow baseline of the stereo cameras during surgical navigation. Effective incorporation of multiple visual cues will be investigated to provide increased robustness for 3D reconstruction, allowing detailed surface map of the tissue under varying operating environment (Fig. 1(a)). The motion characteristics of salient features will also be used to identify tissue deformation in response to instrument interaction.

Visual Servoing: The scanning of large tissue areas with a CLE probe during manual control is particularly challenging. The flexible nature of the probe which makes it is difficult to maintain constant velocity, avoid sudden movements and achieve the precision and stability needed to consistently collect good quality images. For that purpose, robotic-assisted manipulation will be used to facilitate the scanning of large tissue surfaces, introducing high precision and stable positioning of the probe. However, the time needed by the robotic manipulator to scan the tissue under examination might be critical, therefore optimal trajectory planning to ensure efficient surface scanning of a given tissue area is imperative.



(a) **(b)** **(c)**

Figure 1: (a) Dense 3D structure of tissue surface in the abdominal cavity. **(b)** Mapping of a mosaic on the reconstructed tissue surface. **(c)** Fresh breast tissue to be used in a simulated breast cavity.

Mosaicing of endomicroscopic data: To enable the shift from point-based 'optical biopsy' to region analysis, video mosaicing of pCLE data is required to provide a wide field-of-view (FOY) coverage of microscopic information on the tissue surface (Fig. 1(b)). Mosaicing involves the generation of an integrated image or an environment map of a scene from a video sequence by stitching together multiple video-frames. In practice, long sequences of images accumulate misalignment errors when no further correction is applied to the registration. Global alignment or other optimization techniques will be applied to reduce registration errors. The presence of tissue deformation will also be considered.

Computer-Aided Diagnosis: The purpose of this task is to introduce a dense content-based video retrieval approach for CAD. For efficient retrieval, pCLE videos will be represented by visual signatures, invariant to image transformations and illumination changes. To build video signatures, dense descriptors will be applied on each pCLE image to capture discriminative texture information coupled with shape information. To support diagnosis decision, a training database will be built and the most similar pCLE videos from the database to a query video will be extracted.

System Validation: The performance of the proposed framework will be validated on phantom, ex-vivo and in-vivo data. A simulated breast cavity with fresh human breast tissue as shown in Fig. 1(c) will also be used to acquire pCLE data. Ground truth data will be obtained with a laser scanner and a C-arm scanner. To obtain the ground truth position of the camera, optical markers will be fitted on the camera and an optical tracking device (Northern Digital Inc., Ontario, Canada) will be used. The project will include image interpretation training on pCLE breast cancer morphology and teaching on the clinical aspects of breast cancer surgery, current technologies and its challenges. Observation of live operating on breast cancer cases at Charing Cross Hospital and cancer specimen histopathology processing at Histopathology Department, Charing Cross Hospital (including specimen examination under the microscope) will also be organised.

Hardware/software requirements

A stereo laparoscope will be used to capture video data. To generate ground truth data, an optical tracking device (Northern Digital Inc., Ontario, Canada), a laser scanner (Metris MCA v2.5) and a C-arm scanner (GE Innova 4100IQ) will be used. The proposed framework will be implemented in Matlab, C++ and CUDA.

Individual project 28: Platform for microrobot navigation

Supervisors: Henry Ip, Vincenzo Curto and Guang-Zhong Yang

Aims and objectives

The project aim is to model microbot navigation dynamics within a liquid medium and utilising the modelling results to subsequently develop a platform for navigation control. The platform will comprise of magnetic field generation hardware for microbot control and microscope setup for the visualisation of the microbots. The microbots are devices of <100um in length and with minimal mechanical complexity. The outputs of this project provide the theoretical basis and experimental tools for understanding microbot swim dynamics and its relation to microbot structure.

Background

In recent years, increasing interest has been given to the development of micro/nano-fabricated "microbots" as they offer new opportunities for targeted therapies in the form of drug delivery, biopsy and remote sensing. Although microbots are far less sophisticated compared to the average robotic device, their small size (<100um) and possible bio-functionalisation allows them to reach desirable sites in the body through non-invasive means. Figure 1 shows the typical "Helical swimmer" microbots.

The Hamlyn centre will host a state-of-art 3D printer (Nanoscribe Professional GT) capable of producing structures with resolution down to 150 nm for microbot fabrication. However, one of the key challenges of microstructure manipulation in fluids is the navigation against the viscous drag. On this regard, a well-defined magnetic field can be used to steer magnetised microbots along a desired path.

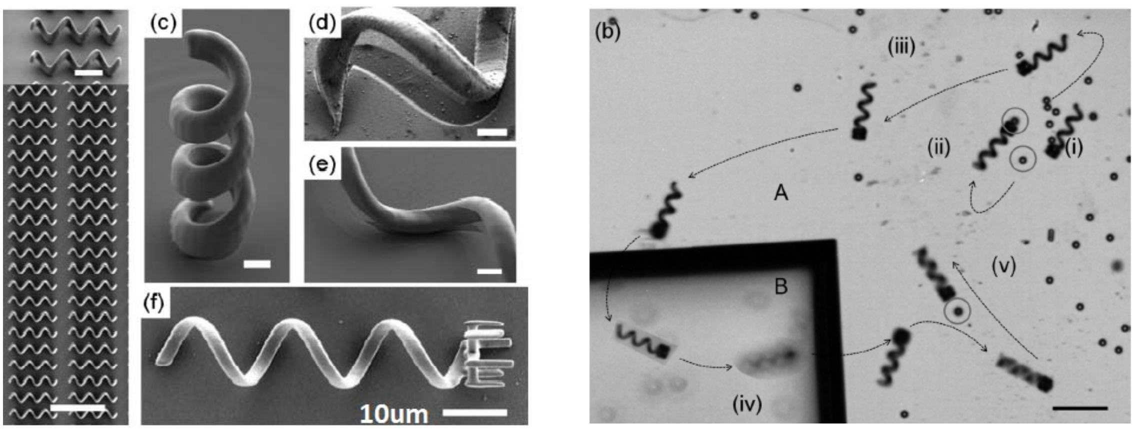


Fig. 1 Helical swimming microbots and navigation

Skeleton project plan

Microbot navigation modelling and control system

The project begins with the study of mathematical models of microbot motion in a viscous liquid for spherical and helical microbots. The result of the study will reveal the range of magnetic field strength required and act as hardware design specifications. Subsequent hardware design includes Helmholtz coil winding and plastic housing. Servo amplifier will need to be interfaced/programmed with a PC to drive the coils. In parallel with the modelling and hardware design, a microscope housing for visualising the swimming microbots will be implemented.

Hardware/software requirements

- 3D printer – for microscope and coil housings
- Power supply
- Servo and PC I/O card
- Gauss meter
- Magnetic beads/3D printed Helical swimmers for testing (optional)

Individual project 29: Physical and Computational Modeling of Light Interaction with Tissue

Supervisors: Daniel Elson and Neil Clancy

Aims and objectives

To simulate the propagation of light in biological tissue using the Monte Carlo technique, build a tissue phantom with controllable optical properties to validate the model, and apply the model to analysis of biophotonic imaging problems.

Background

Imaging techniques in biophotonics attempt to infer properties of tissue by illuminating it and measuring the amount of light transmitted or reflected as a function of wavelength. Relative concentrations of clinically-relevant materials such as haemoglobin, collagen, elastin or exogenous fluorescent markers may then be determined using absorption or fluorescence spectroscopy. However, in order to make quantitative measurements the complex turbid nature of the tissue must be accounted for. Additionally, the optical properties are wavelength-dependent and determine the penetration depth of the light and hence the volume of tissue interrogated. Since the amount of light absorbed by a particular medium is proportional to the optical pathlength in that medium, absorption at longer wavelengths may be overestimated. Previous work in oxygenation studies of the eye and brain have shown that pathlength correction can have a significant effect on the quantitative results obtained.

The aim of this project is to use Monte Carlo modelling to simulate light propagation in tissue for a reflection-based experiment and estimate, as a function of wavelength, the depth of tissue probed by the light, its average pathlength and the fraction that interacts with certain structures such as blood vessels. The code will generate and track the passage of a simulated photon of light through a medium of defined thickness and optical properties. The photon travels a certain distance, defined by the mean free pathlength, before losing a certain amount of a weighting factor due to absorption and proceeding in a random direction partially constrained by the anisotropy factor of the tissue. Analysis of many of these photons (~10^6) allows a statistical picture of light transport in the tissue to be constructed.

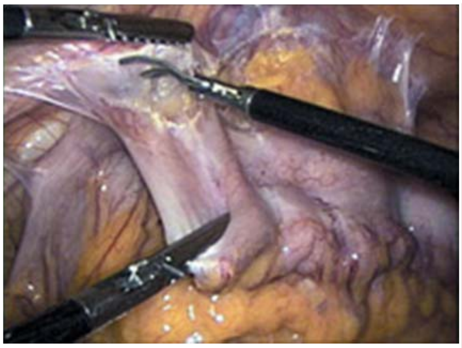
Skeleton project plan

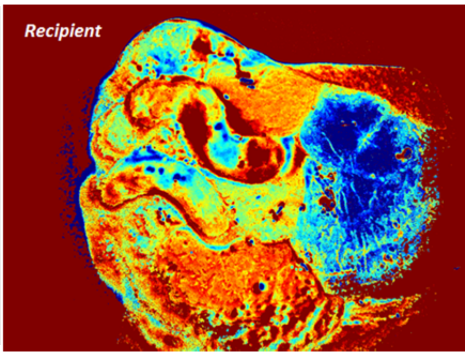
Using core C++ code available online (http://omlc.ogi.edu/software/mc/), a multi-layer simulation will be written to incorporate blood vessels of varying size, as well as other soft tissue structures and smooth muscle. The code will need to be validated on a tissue phantom with controlled optical properties consisting of 'blood' made from haemoglobin powder pumped through silicone tubes in an agar substrate. Scattering will be achieved using polystyrene microspheres.

Following this *in vitro* validation the model will be applied to real tissue using optical properties found in the literature. The simulation will be tailored to fit two different experiments: laparoscopic multispectral imaging and polarisation imaging of the abdomen. In the laparoscopic imaging experiment, the MC results will be used to apply pathlength corrections to absorption spectra from biological tissues to calculate their oxygen saturation. For the polarisation experiment inclusion placed at varying depths in the phantom will be imaged and the depth discrimination capabilities of the instrument will be evaluated and validated.

Hardware/software requirements

- C++
- Matlab
- Consumables for tissue phantom (agar, intralipid, polystyrene spheres, haemoglobin powder, silicone tubing)
- Hyperspectral imaging system
- Polarised light imaging system





Individual project 30: Polarised Stereo Endoscope and Narrowband Detection for Minimally Invasive Surgery

Supervisors: Daniel Elson, Neil Clancy and Jonathon Sorger (Intuitive Inc.)

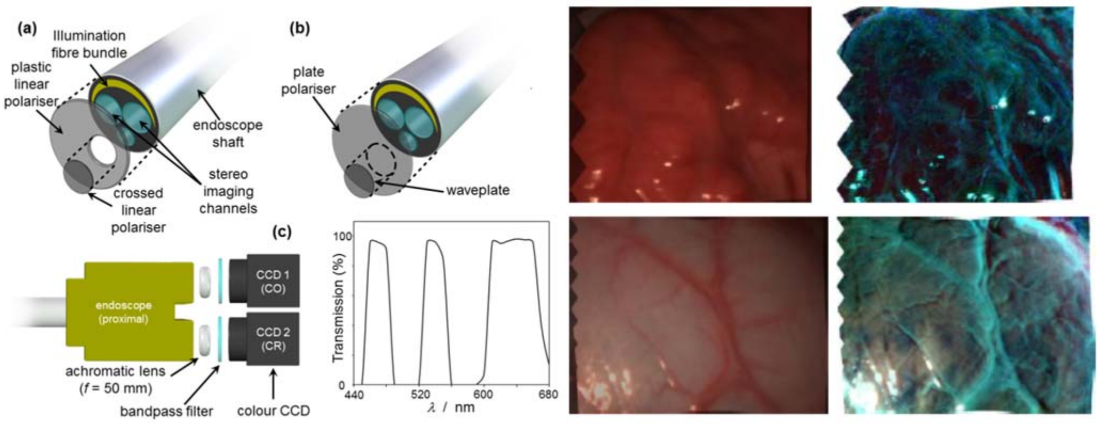
Aims and objectives

The aim of this project is to develop an algorithm to classify different tissue types and disease states using spectral data from a laparoscopic hyperspectral imaging device. The algorithm will be trained using reflectance spectra from known tissue types (e.g., blood vessel, parenchyma, tumour, normal) and then used to identify unknown tissue. The algorithm will be implemented in real-time to allow online identification of tissues of interest.

Background

Analysis and manipulation of the polarisation properties of light reflected by tissue from a polarised input beam have been used to perform different types of biomedical measurements including sub-epidermal skin imaging, colon cancer margin detection, characterization of skin lesions, and visualization of tissues exhibiting dichroic or birefringent properties. It has also been suggested as a means of identifying abnormal tissue during surgery in conditions such as endometriosis where endometrial tissue develops outside the uterus as lesions.

However, thus far most applications have focused on imaging of ex vivo tissue samples or the skin due to the difficulties attached to in vivo imaging such as gaining access to sites of interest during surgery with optical instruments and motion artefacts during acquisition of the multiple images needed. The feasibility of using polarisation during a flexible endoscopy was demonstrated recently in a study of Barrett's oesophagus where cross-polarisation was used to improve the visibility of the microvasculature. Quantitative endoscopic tissue polarisation characterisation using a custom-built laparoscope has also been investigated in ex vivo tissue. However, signal level, motion artefacts and acquisition speed remain a challenge for in vivo use



The Intuitive triple channel endoscope and polarization-enhanced images of porcine tissue in vivo.

Skeleton project plan

A stereo endoscope provided by Intuitive will be adapted to allow snapshot acquisition of orthogonal linear polarisation images to generate difference of linear polarization images. These images are acquired in three narrow bands using a triple-bandpass filter and pair of colour cameras. The ability to detect optical signals as a function of depth will be tested with a range of different optical phantoms. The information gained both by polarization and stereo will be evaluated and a system of augmenting the white light images with additional details will be investigated. Finally, experiments in vivo will assess the potential for disease detection, possibly involving an animal lab at Intuitive Inc. CA.

Hardware/software requirements

- LabVIEW/Matlab/C++
- Intuitive triple channel endoscope
- Polarization optics and cameras
- Light sources and fresh tissue.

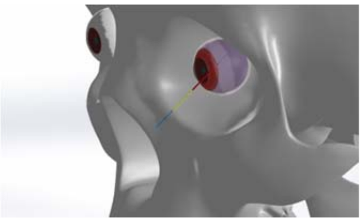
Qi et al. Biomed Opt Exp 3, 2156 (2012)

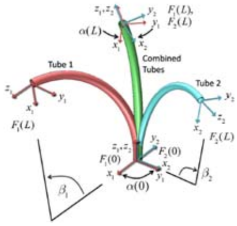
Wood and Elson Biomed Opt Exp 1, 463 (2010)

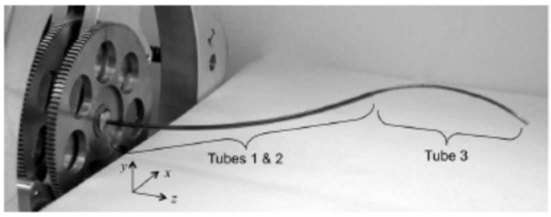
Qi et al. Biomed Opt Exp 4, 2433 (2013)

Project number 31: Miniaturised Concentric Tube Robot for Micromanipulations in Vitreoretinal Surgery

Supervisors: Dr. Christos Bergeles and Prof. Guang-Zhong Yang







Aims and objectives

Simulate, design and assemble a mechatronic system for the deployment and control of concentric tube robots with sub-millimetre dimensions.

Background

Blinding eye pathologies are affecting a significant number of the human population. Diseases like retinal vein occlusion, and epiretinal membrane formations are surgically treatable, but they require extremely delicate manipulations and close to superhuman dexterity. After all, the structures of the eye, e.g., the retinal vessels and retinal depth, have dimensions of only a few hundred micrometres. As a result, ophthalmic surgery is one of the most demanding fields in surgery, and a field where robotic assistance if of profound importance. This project aims to develop a prototype flexible ophthalmic surgery robot based on the concentric tubes technology.

The robot will be miniaturised so that is can be easily incorporated in the surgical workflow, and will enable precise localised manipulations near the retina.

Skeleton project plan

1) First, the student will familiarise himself with the technology of concentric tube robots, by performing a literature survey, and identifying the common elements of existing systems and the internationally competing research laboratories.

2) Second, he/she will conduct research on the design and construction of the actuation of a concentric tube robot system suitable for the micromanipulations required in the environment of the human eye. This work will be based on existing work that has already been conducted at the Hamlyn Centre and at the research laboratory of our international collaborator.

3) Subsequently, the student may elect to focus his attention on several discrete and novel components, e.g:

(a) rapid prototyping of flexible tubes using 3D printing technologies (metal/plastic).

(b) mechanical FEM simulation of super-elastic tubes with respect to mechanical stiffness alterations.

(c) control algorithms for controlling the robot shape and its end effector.

4) Finally, the student will conclude his project by demonstrating the performance of the system in a surgically-relevant scenario.

Hardware/software requirements

To design the mechatronics system, knowledge of Solidworks (or an equivalent CAD program) is **necessary**.

To control the mechatronics system, knowledge of Arduino is a **plus.**

To simulate and rapidly prototype the software, knowledge of Matlab is a **plus.**

To develop higher level control algorithms, knowledge of C++ is a **plus.**

Individual project 32: A miniaturised Robotic Probe for Real-Time Intraoperative Fusion of Ultrasound and Endomicroscopy Scanning

Supervisors: Petros Giataganas and Professor Guang-Zhong Yang

Aims and objectives

Develop a miniaturised robotic probe with real-time fusion techniques combining macroscopic ultrasound with microscopic confocal images using novel robotic scanning mechanisms and adaptive visualisation techniques.

Background

Currently the diagnosis during cancer surgery is mostly based on histopathological analysis of discrete biopsy specimens taken during surgical procedures. This process tends to be inconsistent, not ‘real-time’ and there is a significant demand clinically for reducing the invasiveness and potential of re-excision. Fibre-based endomicroscopy is an emerging technique for real-time highly magnified continuous visualisation of histological details for in vivo and in situ assessment of tissue pathology, a process known as “optical biopsy”. However, optical imaging techniques lack of depth visualisation as they can image only superficial tissue layers. In contrast, ultrasound provides a versatile imaging modality for investigating tissue structure and function in real-time. Ultrasound images provide improved depth visualisation but have reduced imaging resolution. Therefore, to increase the diagnostic yield of intraoperative histological assessment and potential cancer detection thus decreasing the time to therapeutic decision, the combination of ultrasound depth images with endomicroscopic superficial images through robotic actuated scanning is proposed.

The purpose of this project is to develop a novel robotic actuation scheme that can combine a laparoscopic ultrasound array with a scanning endomicroscopic mechanism. As a result, the system can provide simultaneously 2D ultrasound depth images with enlarged mosaics of endomicroscopic

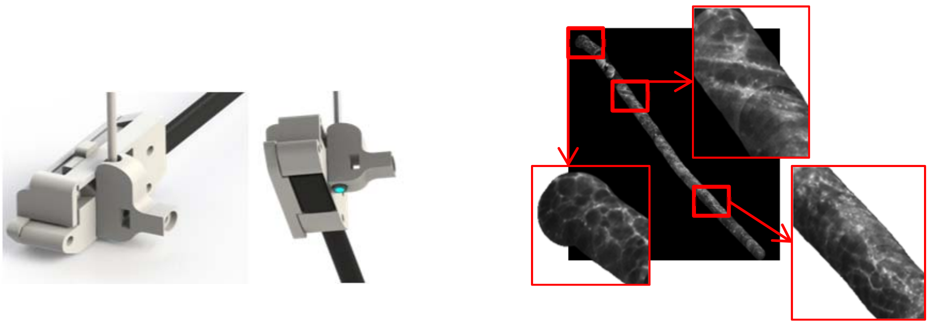


Figure: (Left) Initial under-development concept for combining ultrasound images with an ch for endomicroscopy probe. (Right) Resulting large area mosaic of fat tissue combining multiple microscopic images.

Skeleton project plan

The candidate needs to have strong background in mechatronics and be proficient in programming, mainly in image processing, and user interface design.

Specific steps and milestones of the project include:

- Endomicroscopic image mosaicking and real-time implementation;
- 3D tissue reconstruction through ultrasound scanning images;
- Fusion of 3D reconstructed structures with superficial endomicroscopic mosaics;

- Design of a novel robotic actuator to integrate the aforementioned fusion approach;
- Visualisation, system integration and phantom validation;
- User interface design and real-time programming;

Hardware/software requirements

- Matlab / Labview simulation
- C/C++ programming
- Actuation design and 3D Rapid prototyping

Individual project 33: Force Adaptive Control of an Articulated Instrument with Ultrasound Probe and 3D Image Construction

Supervisors: Dr. Jianzhong Shang, Mr Petros Giataganas, Professor Guang-Zhong Yang

Aims and objectives

Develop a laparoscopic instrument for robotically-assisted ultrasound scanning with force adaptive control and novel robotic actuator schemes. Objectives of this project: Articulated instrument design; Force adaptive control of ultrasound scanning; 3D image reconstruction.

Background

Laparoscopic ultrasound offers a versatile imaging platform for intraoperative real-time tissue structure imaging and provides also functional information such as blood flow. There is therefore extensive evidence to document the superiority of intraoperative ultrasound in diagnosing and staging for malignancy. However, in a minimally invasive surgical scenario, it is challenging to acquire consistent ultrasound images as the surfaces are not uniform and the fulcrum effect hinders its operation.

The aim of this project is to develop an instrument for ultrasound scanning with force adaptive control. The instrument will be a laparoscopic-style that has an ultrasound probe at the distal tip and actuators located at the back. The ultrasound probe will make one degree of freedom scanning while maintaining its orientation (parallel movement) and constant contact force. The 3D volume of under-scan structures will be constructed using the adjacent slices of acquired images.

Skeleton project plan

The candidate needs to have strong background in mechatronics and be proficient in programming, mainly in image processing, and user interface design.

Specific steps and milestones of the project include:

- Literature review on state of the art technologies;
- Mechanical design, simulation, manufacturing involving internal facilities and external companies, and integration/assembly;
- Force adaptive control;
- 3D image reconstruction;
- Lab tests and clinical application tests;
- A technical paper from the result of this study.

Hardware/software requirements

- SolidWorks
- Ansys
- Precision Engineering and Mechanical Workshop facilities
- Force sensor
- Motors and controllers
- C/C++ programming
- Ultrasound probe and image acquisition unit.