PHD STUDENTSHIP PROJECT PROPOSAL: BRC PROJECTS

PROJECT DETAILS	
Project Title:	Developing artificial intelligence and machine learning to define pelvic anatomy and pelvic tumours on MRI for disease monitoring and treatment planning.
Short Project Title:	**Developing artificial intelligence and machine learning on MRI of pelvic tumours**
SUPERVISORY TEAM	
Primary Supervisor(s):	Prof. Dow-Mu Koh
Additional members of the supervisory team:	Dr. Matthew Blackledge Dr. Christina Messiou [Dr. Gigin Lin (Taiwan), External Supervisor] Dr Alison Tree
Lead contact person for the project:	Prof. Dow-Mu Koh
DIVISIONAL AFFILIATION	
Primary Division:	Radiotherapy and Imaging
Primary Team:	Functional Imaging Team
PROJECT PROPOSAL	

BACKGROUND TO THE PROJECT

Artificial intelligence (AI) and machine learning (ML) are rapidly changing the landscape of radiology. AI and ML have the potential to aid tumour detection across the body, provide segmentation of disease and normal anatomy for treatment planning, as well as the automatic tracking of tumours during treatment.

In diagnostic imaging, MR images derived from morphological and functional imaging can yield diagnostic, response or prognostic biomarkers. However, quantitative and radiomics analysis of images depends on accurate tumour identification and segmentation, but manual image segmentation is often prohibitively time-consuming and is associated with interobserver variations. Automatic or semi-automatic tools that can aid the radiologist to rapidly identify and perform tumour segmentation would increase the usage of quantitative imaging in oncology, be an enabler for radiomics research and improve the curation of prospective imaging data for developing future AI and ML-based imaging tools.

In radiotherapy, recent developments in MR-only simulation and therapy planning workflow, as well as the advent of MR-Linac systems, necessitate developments in tumour definition and segmentation using MR images to optimise treatment planning. Furthermore, there is a need to identify organs-at-risk comprising normal anatomical structures to minimise toxicity to normal tissues. Hence, the development of novel algorithms and tools that would facilitate the rapid assessment of gross tumour volume (GTV) and organs at risk using MR images would be welcomed.

In this proposed PhD project, we will investigate, develop and apply computational imaging algorithms that will identify normal pelvic anatomical structures and detect pelvic tumours (including cervical and rectal cancers), as well as perform volumetric tumour segmentations for use in radiological and radiotherapy clinical applications. This project will be underpinned by existing research collaborations with the Chang Gung Memorial Hospital (Taipei) and Queen Mary Hospital (Hong Kong).

PROJECT AIMS

- To design and optimize ML algorithms for identifying normal pelvic organs and anatomy on MRI
- To design and optimize ML algorithms to detect and segment cervical cancers on MRI, and to generate volumes of interest for radiological and radiotherapy applications
- To design and optimize ML algorithms to detect and segment rectal cancers on MRI, and to generate volumes of interest for radiological and radiotherapy applications

RESEARCH PROPOSAL

<u>Year 1</u>

- High-quality MRI image datasets, which should comprise at least T1 and T2-weighted imaging, will be obtained for use throughout the PhD in training and testing the ML algorithms. Images will be analysed for their geometric fidelity, spatial resolution, ability to depict pelvic anatomy and contrast resolution for diseases. It is anticipated that T2-weighted imaging will be used as the main imaging sequence for analysis.

- 100 pelvic CT and MR scans comprising the above sequences in male and female patients will be used as training data with a range of machine learning algorithms to identify normal pelvic anatomy and structures, including those relevant to radiotherapy. Definition of normal organ boundaries in the training data will be derived from: (1) CT imaging studies with contours from radiotherapy planning; (2) radiologist-defined organ contours on MR images. Transfer learning methods will be used to transfer features of the organ contours learned from the CT images into the MR segmentation algorithms, and the ground truth MR contours defined by expert radiologists/radiation oncologists will be used as the target output of the ML training for the MR image segmentation.

- It is feasible that, despite being driven by ground-truth expert-derived segmentations, the ML performance when segmenting normal anatomy will be adversely affected by any abnormalities that are present in the training data. The locations of these abnormalities will also be available, so image models will be developed using both machine learning and conventional techniques to synthetically in-fill these regions to appear normal. Training data edited in this way will be used for learning the normal anatomy segmentations, and the quality of the in-fill models will be determined by assessing the improvement in normal anatomy segmentation performance.

- Data curation by the Research Team of cervical and rectal cancer MRI images from Taiwan, Hong Kong and the UK will form the basis the work in Year 2 and Year 3. In Year 1, volumetric segmentations of tumours of cervical cancers will be drawn individually and in consensus by a team of radiologists and radiation oncologists on T2-weighted MRI, and annotated with metadata that includes clinical, pathological and other laboratory information.

- In the First Year Report, the candidate will report on the MRI image dataset obtained, the algorithms investigated, and the results obtained for defining normal pelvic anatomy in the pelvis on MRI images. The preparation of a scientific manuscript will also be encouraged at the end of the First Year.

<u>Year 2</u>

- The manually segmented and annotated MRI images of patients with cervical cancer will be used as training data to optimise ML algorithms to identify and segment cervical cancers. Transfer learning methods will be developed to incorporate the normal features learned from the work in year 1 to the harder task of segmenting abnormal tissues. The tumour segmentations will be compared with expert defined segmentations and the machine diagnostic performance recorded. The algorithms will be applied to a validation image set of segmented and annotated MRI studies of cervical cancer patients acquired from another institution and the diagnostic performance of the algorithm determined.

- The student will adapt, develop and apply algorithms to undertake the above analysis.

- In Year 2, volumetric segmentations of tumours of rectal cancers curated from the participating institutions will be drawn by a team of radiologist and radiation oncologists individually and in consensus on T2-weighted MRI, and annotated with metadata that includes clinical, pathological and other laboratory information. The data will be prepared for use in Year 3 of the PhD.

- The PhD student will plan to submit at least one scientific abstract based on the Year 2 work to an international meeting.

Year 3

- The manually segmented and annotated MRI images of rectal cancer will be used as the training set to optimise an AI/ML algorithm (from transfer learning) to identify and segment rectal cancers. Transfer learning methods will be developed to incorporate the normal features learned from the work in years 1 and 2 to the task of segmenting abnormal tissues. The tumour segmentations will be compared with expert defined segmentations and the diagnostic performance recorded. The best performing algorithm will be applied to a validation image set of segmented and annotated MRI studies of rectal cancer patients acquired from another institution and the diagnostic performance of the algorithm determined.

- The student will adapt, develop and apply algorithms to undertake the above analysis.

- The student will publish their preliminary methodological development work in a peer-reviewed journal.

Year 4

- The student will investigate and explore additional novel developments that may improve the performance of the ML algorithms, including the use of anatomical atlas data as another source of information for use with transfer learning. The incorporation of multichannel learning data into novel learning algorithms will also be explored, determining the improvement in segmentation accuracy once additional imaging contrasts have been included.

- The student will explore the potential for a joint patent with participating institutions for the algorithms developed.

- After all data analysis is completed, the student will start writing the PhD thesis with an aim to complete all chapters at least 8 weeks before the submission date. The student is also expected to write and submit for publication at least one journal article for potential publication in a high impact scientific journal.

EXPLAIN BRIEFLY HOW THIS PROJECT WILL PROVIDE A TRANSLATIONAL TRAINING EXPERIENCE FOR THE STUDENT.

The student will work within a multidisciplinary team in a hospital/ scientific environment, which will provide ample opportunities for the student to learn about the relevance of their work and research towards patient care and disease outcomes. The student will acquire new skills in AI/ ML and learn how to apply these practically and in a clinically meaningful way to build new tools that can help radiologists and radiation oncologists to work more effectively.

This project provides an excellent opportunity for the student to translate science to practice; and student learning will be supported by a strong supervisory team that comprises experts in physics, computational analysis, radiologists and radiation oncologists. In addition, existing research collaborations with Chang Gung Memorial Hospital (Taipei) and Queen Mary Hospital (Hong Kong) will provide access to expert help and support in AI/ML; as well as multicentre clinical trial training required for this project.

LITERATURE REFERENCES

1. Erickson BJ, Korfiatis P, Akkus Z, Kline TL. Machine Learning for Medical Imaging. Radiographics. 2017;37(2):505-515.

2. Salvatore C, Cerasa A, Battista P, et al. Magnetic resonance imaging biomarkers for the early diagnosis of Alzheimer's disease: a machine learning approach. Front Neurosci. 2015;9:307.

3. Shen D, Zhang D, Young A, Parvin B. Machine Learning and Data Mining in Medical Imaging. IEEE J Biomed Health Inform. 2015;19(5):1587-1588.

4. Zhou M, Scott J, Chaudhury B, et al. Radiomics in Brain Tumor: Image Assessment, Quantitative Feature Descriptors, and Machine-Learning Approaches. AJNR Am J Neuroradiol. 2017.

5. Wang J, Wu CJ, Bao ML, Zhang J, Wang XN, Zhang YD. Machine learning-based analysis of MR radiomics can help to improve the diagnostic performance of PI-RADS v2 in clinically relevant prostate cancer. Eur Radiol. 2017;27(10):4082-4090.

CANDIDATE PROFILE

Note: the ICR's standard minimum entry requirement is a relevant undergraduate Honours degree (First or 2:1)

Pre-requisite qualifications of applicants: e.g. BSc or equivalent in specific subject area(s)	BSc or equivalent in specific subject area(s)
Intended learning outcomes: Please provide a bullet point list (maximum of seven) of the knowledge and skills you expect the student to have attained on completion of the project.	- Deep learning for the automatic or semi-automatic identification and segmentation of normal organs and pelvic cancers (cervical and rectal) - Understanding applied physics and computational analysis for medical applications - Medical image processing techniques - Clinical trial design and applications in cancer - Working within a multi-centre trial - Handling of imaging data including checking for data integrity (QA/QC), data archival and storage, data retrieval, data annotation and data analysis.