Inverse Problems in Medical Imaging and Radiation Therapy with applications using Microwaves, X-rays, and Gamma-rays.

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With the discovery of x-rays and gamma rays in the late 1800’s ionizing radiation started to play an important part in the detection and cure of cancer. We have come a long way since then, and advanced medical imaging systems and isocentrically rotating linear accelerators currently perform a vital role in the early detection of tumors, in diagnosing disease and providing precision guidance and treatment for radiation therapy and radiosurgery. While X-ray mammography, Computed Tomography (CT), Positron Emission Tomography (PET) and Intensity Modulated Radiotherapy have made a profound difference to our ability to detect, diagnose, monitor and treat disease, they also have a number of disadvantages. Mammography has a high false-positive rate and is often uncomfortable; the increased usage of CT and PET is raising the population dose; organ motion during radiotherapy remains a challenge, and the benefits of advanced technologies are often not available to remote or low-income communities.

Systems that attempt to reconstruct the characteristics of the object in question (such as a moving tumor) from measurements of the interactions of radiation with the surrounding material are examples of inverse and often ill-posed problems. In CT, the complementary nature of electron density and atomic number can result in “invisible” media. Making informed use of x-ray scatter, can improve the accuracy of the reconstructed attenuation coefficients, and reduce the number of projections and dose, for an equivalent image quality. In PET, the use of scattered photons can provide attenuation correction without the need for separate CT or Magnetic Resonance images and improves the image contrast for a given activity. Cone Beam Megavoltage Electronic Portal Imaging devices have been used to detect organ motion within the patient even in the presence of a rotating gantry and can be used to calculate and optimise the delivered radiation dose. Finally, Breast Microwave imaging, a safe, low cost, and comfortable approach has been developed and shown to detect 4 mm breast lesions in the lab and to classify lesions with a specificity of 90%. We continue to develop microwave detection systems, algorithms that correct for propagation speed and attenuation in an inhomogeneous medium and to automatically classify the presence of a lesion. This presentation will focus on some of our research in Breast Microwave Imaging, Scatter Imaging of X- and gamma-rays, and the development of techniques to track and predict, in real-time, the motion of tumors to optimise the complication-free cure.