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Image Formation in Bio-optical Sensing[1]

ERIC MILLER, Tufts University

Over the past two decades a number of optical sensing methods have emerged with potential to provide complementary information to traditional medical imaging modalities in application areas ranging from basic science to disease diagnosis and treatment monitoring. Though still largely in the research and development stage, modalities including diffuse optical tomography (DOT), fluorescence molecular tomography (FMT), photo-acoustic tomography (PAT), and bio-luminescence tomography (BLT) have excited much interest due to their natural functional imaging capability, their relatively low cost, and the fact that none required the use of ionizing radiation. These advantages however are tempered by a number of challenges associated with the processing of these data. Specifically, these data types all rely in one way or another on the interaction of light with tissue. The diffusive nature of this interaction inherently limits the spatial resolution of these modalities. As a result the process of forming an image is a far more delicate task than is the case with more standard imaging modalities such as X-ray computed tomography (CT). Two basic methods have been explored to address the ill-posedness of these problems in order to improve the information content in the resulting images. The optical data may be augmented either through the use of spectral diversity or by attempting to integrate optical data types with information from other modalities such as CT or MRI. Alternatively, a mathematical technique known as regularization can be used to impose physically-based constraints on the reconstruction. In this talk, I shall provide an overview of the work in my group in optical image formation within the contexts of DOT for breast cancer imaging and FMT for small animal imaging. The focus of the talk will be on methods that integrate data augmentation and mathematical regularization. In the case of FMT, we shall discuss our work in combining the optical data with information provided by CT concerning the structural distribution of tissue classes within the region of interest. Here, we have developed a number of spatially-varying regularization methods which use the CT data to help constrain the FMT reconstruction and obtain imaging results that are substantially improved over classical regularization techniques. For DOT, we have recently been considering the use of hyperspectral data sets in which information from over 100 near infrared wavelengths is made available to the processing. When combined with a regularization scheme based on parameterizing the images in a geometric manner, we believe that it will be possible to produce a standalone DOT system with spatial resolution that is today only achieved by combining DOT with e.g., CT.

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