Leveraging multiple imaging modalities to improve breast cancer detection, diagnosis, and management

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Breast cancer is the most common malignant disease in women, and the second leading cause of cancer death among American women today [1]. The primary tool for detection and diagnosis of breast cancer is x-ray mammography, but it is hoped that additional information provided by Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) will provide a means to determine if a suspected lesion, seen in mammography, is malignant or not. The procedure may prevent a large number of retrospectively unnecessary breast biopsies, a surgical procedure, which can result in pain, bruising, and scaring, that is presently used to evaluate suspected breast lesions.

PET (Fig. 1) provides information on the metabolic activity of the tissue. Malignant lesions that are generally more active than the surrounding tissue are often distinguishable in these images by their higher intensity. PET however, lacks the structural information that can be invaluable when identifying the location or context for the lesion, such as for planning biopsies or radiation treatment. This structural information can be provided by MRI (Fig. 2).

In order to maximize the benefit of acquiring both PET and MRI the images need to be registered (brought into spatial alignment), and fused (combined into a single image for inspection by the radiologist). Registration of PET and MRI breast images is difficult since the breast is composed of soft, highly deformable tissue, without any internal salient structures. Finite element procedures using ANSYS Academic Products provided a means to achieve this task.

Fiducial skin markers (FSMs) visible in PET and MRI (taped to predetermined locations on the skin of the breast prior to data acquisition) and identical patient positioning during PET and MRI scans (to ensure similar stress conditions) are applied during data acquisition. A finite element model of the breast is constructed from the high resolution MRI image (Fig. 3). Displacements between corresponding FSMs are used to calculate the displacement for each node in the meshed breast. This displacement field is estimated by first distributing the observed FSM displacement vectors linearly over the breast surface and then distributing throughout the volume. This process has been implemented using the ANSYS software heat transfer module. An analogy between displacement and the temperature in steady state heat transfer in solids is used to find a dense displacement field from the observed displacements (loads) at the FSMs.
If Computed Tomography (CT) data is available and coregistered with the PET image, such as from a PET/CT scanner, an additional refinement process can be performed. A large number of corresponding surface points can be identified in the MRI and CT images. The displacements at these points can be used to deform the mesh a second time, reducing the small registration errors that still exist in regions away from the FSMs.

Using the resulting displacement field the MRI image can be warped to the PET image (Fig. 4). The region of activity in the PET image clearly correlates better with the glandular tissue region visible in the MRI image after FEM registration, as compared to rigid registration only. More information about this registration process can be found in [2-5]. Current work focuses on determining the optimal way to present the registered images to the radiologist [5].

References: