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Three Dimensional Tissue Motion Analysis from Tagged Magnetic Resonance Imaging

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Abstract

Motion estimation of soft tissues during organ deformation has been an important topic in medical imaging studies. Its application involves a variety of internal and external organs including the heart, the lung, the brain, and the tongue. Tagged magnetic resonance imaging has been used for decades to observe and quantify motion and strain of deforming tissues. It places temporary noninvasive markers-so called "tags"-in the tissue of interest that deform together with the tissue during motion, producing images that carry motion information in the deformed tagged patterns. These images can later be processed using phase-extraction algorithms to achieve motion estimation and strain computation.

In this dissertation, we study three-dimensional (3D) motion estimation and analysis using tagged magnetic resonance images with applications focused on speech studies and traumatic brain injury investigation. Novel algorithms are developed to help tagged motion analysis. Firstly, a pipeline of methods (TMAP) is proposed to compute the 3D motion from tagged and cine images of the tongue during speech. TMAP produces an estimation of motion along with a multi-subject analysis of motion pattern differences between healthy control subjects and post-glossectomy patients. Secondly, an enhanced 3D motion estimation algorithm (E-IDEA) is proposed. E-IDEA tackles the incompressible motion both on the internal tissue region and the tissue boundaries, reducing the boundary errors and yielding a motion estimate that is more accurate overall. Thirdly, a novel 3D motion estimation algorithm (PVIRA) is developed. Based on image registration and tracking, PVIRA is a faster and more robust method that performs phase extraction in a novel way. Lastly, a method to reveal a muscle's activity using strain in the line of fiber directions is presented. It is a first step to relate motion production with individual muscles and provides a new tool for future clinical and scientific use.

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