Visualization and Electronic Anatomic Atlases for Medical Imaging

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Visualization has central importance in radiology for diagnosis and therapy. The detection, localization, and characterization of abnormalities depends on their conspicuity and differentiation from normal structures and their variations. Conventional x-ray radiography and motion tomography has been augmented by medical imaging modalities, such as CT and MRI, that exploit physical and functional differences in normal and pathologic structures to create images with better contrast, spatial resolution and fewer artifacts. Subjective analysis of medical images obtained using computer graphics visualization methods has been studied extensively, and the limitations of commonly used medical imaging methods are well known and understood. Fusion of images obtained with multiple medical imaging modalities presents a new challenge for visualization systems that must handle 3, 4 or higher dimensional image data.

In this presentation, the fundamental principles of visualization systems applied to medicine will be defined and illustrated. Basic principles of image formation, subjective interpretation and application needs will be delineated, and limitations of current technology will be described. Multidimensional imaging, especially multispectral, multimodality and multitemporal visualization and analysis will be described in qualitatively and quantitatively. The use of visualization systems for image guidance in minimally invasive diagnostic and therapeutic procedures will be described. The incorporation of a priori information in the reconstruction of images from measurements and their visualization will be defined.

Electronic atlases of the body are spatial arrays linked to a hierarchical knowledge base of anatomic nomenclature, functional and vascular territories, and related textual or symbolic reference data. Electronic atlases are used for teaching anatomy, image reconstruction, morphometry and medical image analysis.

Individualized electronic atlases are synthesized by pairwise matching of a normative atlas to superimpose on a target (e.g., patient) volumetric imaging study. This is accomplished by defining the original atlas as a deformable template that is transformed to a target anatomy.

The methods for forming anatomic atlases, labeling them, and synthesizing individualized versions will be explained and illustrated. Global pattern matching, an application of Grenander's global pattern theory, will be introduced as the mathematical basis for determining the transformation needed to deform the original atlas to a target shape under rigorously defined topological constraints.

The application of electronic atlases to automated segmentation, probabilistic generalization to test for group differences, radiotherapy treatment planning and evaluation, and others will be described.

Educational Objectives:
1. Introduce electronic atlases and their application
2. Define the mathematical basis of global pattern matching
3. Describe the use of deformable probabilistic atlases in medical imaging analysis.