Chapter XIII
Combining Geometry and Image in Biomedical Systems: The RT TPS Case

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ABSTRACT

Patient anatomy, biochemical response, as well functional evaluation at organ level, are key fields that produce a significant amount of multi modal information during medical diagnosis. Visualization, processing, and storage of the acquired data sets are essential tasks in everyday medical practice. In order to perform complex processing that involves or rely on image data a robust as well versatile data structure was used as extension of the Visualization Toolkit (VTK). The proposed structure serves as a universal registration container for acquired information and post processed resulted data. The structure is a dynamic multidimensional data holder to host several modalities and/or Meta data like fused image sets, extracted features (volumetric, surfaces, edges) providing a universal coordinate system used for calculations and geometric processes. A case study of Treatment Planning System (TPS) in the stereotactic radiotherapy (RT) based on the proposed structure is discussed as an efficient medical application.

INTRODUCTION

Computer aided medical applications for diagnosis, therapy, simulation or training proliferate gradually in everyday practice heavily relying on image data (Dawson and Kaufmann, 1998; Spitzer & Whitlock, 1998). Radio therapy planning, surgery as well medical simulation requires anatomic and physical modeling of the whole or part of the human body. Further on in silico functional study of the human body physiology requires the interoperation of several models to
approximate an as real as possible behavior (Noble, 2002; Gavaghan, Garny, Maini, & Kohl, 2006; Seemann, Hoeper, Doessel, Holden, & Zhang, 2006). Major sources of real world data related to anatomical details are tomographic image sets. Tomographic image sets of 3D solid objects are in general stacked 2D cross-sectional images of the inspected object that contain geometric information mixed with material properties of the solid in terms of radiation absorbance.

The modality used to obtain the tomographic set determines the geometric accuracy of anatomical regions, the resolution of material properties as well functional characteristics. The almost annual doubling in computer power permits today real time manipulation of simultaneous multimodal datasets representation also know as image fusion and 3D image registration. Sometimes modalities act complementary in cases of sparse acquired datasets (Shim, Pitto, Streicher, Hunter P. J. & Anderson I. A. 2007). In order to study physiological function of internal organs several models have been proposed ranging from simple calculation diagrams to complex animated 3D solid models (France et al. 2005; Noble 2002; Seemann, 2007; Selberg & Vanderploeg, 1994; Spirka & Damasa, 2007). Almost all models involve dynamics and geometry. Physiological functions rule dynamics, dynamics produce data and data become finally visualized (Freudenberg, Schiemann, Tiede, & Hoehne, 2000). Soft tissue simulation used extensively in computer assisted surgery planning or training is an example. Tissue is modeled as a deformable object while collision detection between the virtual surgery instruments or even neighbor organs is used. Deformation is modeled according to physiological data while collision detection queries the geometric models to undertake the desired action for example simulated tissue ablation, rapture (Nealen et al. 2005; Teschner et al., 2005).

The Visible Human Project is another reference project that serves educational as well research (Ackerman 1998; Robb & Hanson 2006). Using the multimodal sets of the project (CT, MRI, CRYO) volume reconstruction of the human body both female and male is possible. Especially today where computational power and special graphics hardware is widely available at the cost of regular home personal computer the realization of a virtual dissection is feasible (Spitzer et al. 2004). One successful example is the Voxel-Man navigator (Schiemann, Tiede & Hoehne, 1997). Image guided techniques can assist both surgery and diagnosis. Virtual Endoscopy is an example of simulated endoscopic examination for diagnostic purposes (Robb, 1999). Reconstruction of the anatomy is done using tomographic imagesets and a fly through visualization is adopted to provide the analogous of real endoscopy. Once again improvements in the medical scanning systems combined with progress in computer systems lead to a novel approach of diagnostic medical imaging. Finally therapy planning systems in medicine make extensive use of imageset. Either directly or indirectly used to extract volumetric – geometric characteristics and 3D models those systems become essential in calculating complex therapeutic schemes like stereotactic radiotherapy, IMRT, neurosurgery, liver surgery orthopedics surgery etc (Mock et al. 2004; Shim et al. 2007).

All these systems are relative new and are undergoing an evaluation period where knew concepts from already established knowledge areas are reused. An example mentioned above is collision detection. Collision detection concept serves gaming from the very first day when primitive bouncing ball games debuted to the virtual reality implementation of industrial standard simulators. Data structures are continuously tested in the complex field of computer visualization.

Finally the most critical part is the man machine interface. But poor human interaction with application’s functional dynamics can render useless even a state of the art system. Thus a lot of new techniques, input devices, displays, and controllers exist to fulfill the principal need for as possible high reality representation of the real world.