Linking Ontologies with Three-Dimensional Models of Anatomy to Predict Physiological Effects of Penetrating Injuries

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Motivation:
We are interested in predicting the anatomic and physiological effects of penetrating injury. The underlying technology will need to link segmented 3-d geometrical models with anatomical models, in order to simulate both the direct and indirect effects of a projectile injury.

Methods:
Anatomic knowledge, such as which organs are in a region of the body and how they relate to other components, can be represented in an ontology. Ontologies provide formal definitions of concepts and relationships among concepts. One source of anatomic knowledge is the Digital Anatomist Foundational Model (FMA), a domain ontology that represents a coherent body of explicit declarative knowledge about human anatomy. The FMA provides formal definitions of detailed anatomical concepts and relationships of anatomic structures in a computationally-accessible format. However, it lacks information on organ shape and absolute location.

Conversely, geometric knowledge regarding the location and shape of organs is represented in a 3-d geometric model. These models may be segmented to identify organ parts and sub-parts. While geometric models contain detailed information on organ *location and shape*, the anatomical knowledge about the segmented structures remains in the head of the viewer.

Geometric and ontologic models of anatomy exist in largely disjoint worlds.

We are developing methods to integrate these two worlds so that software can relate geometry to anatomic structures in the FMA. For example, software could reason about remote consequences of a localized injury by identifying the site of injury in the geometrical model, referencing the anatomic entities associated with that site, and working through relationships in the FMA to establish the other anatomic structures that are also likely affected because they are related to the injured organs.

Our approach is based on developing an ontology of various geometric models that are used by many groups to represent an organism from segmented volumetric image data. This ontology allows components within a geometric model to be annotated with terms in the FMA in order to link geometry and anatomy (Figure 1).

A path of destruction can be specified in the geometrical model, and a set of intercepted geometrical elements can be deduced (Figure 2). These geometrical elements can be mapped to the FMA to infer the organs that are injured.

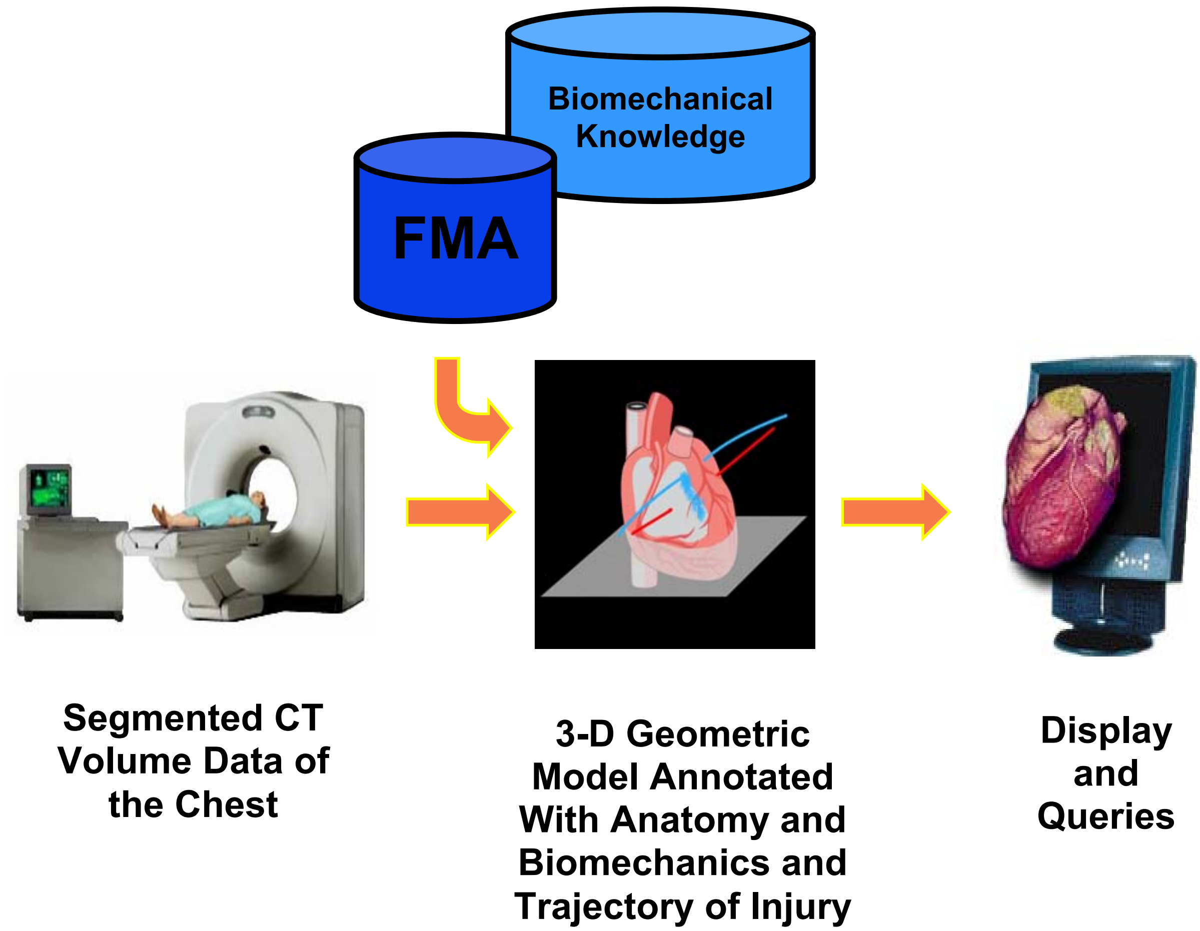

Figure 1. Overview of process for building geometric models from source images. CT scan data are processed to create 3-d models of anatomy. These models are linked with knowledge in the FMA as well as with other knowledge such as biomechanical tissue properties.

Results:

We have developed a 3-d geometry ontology and will show how it can be used to add anatomic information to geometric models. Our geometry ontology represents a spectrum of primitive geometric elements used to construct 3-d geometrical models, such as points, cells, meshes, and simplexes. These geometric elements relate to various attributes needed to simulate the effect of penetrating injury, such as boundary features, externality, and physical properties.

From a volumetric image data set of the chest, we produced 3-d geometric models of the heart (Figure 2). The anatomic structures, such as the ventricles and aorta, are labeled in the geometry. We have superimposed a projectile trajectory and deduced the path of injury and produce a list of damaged structures (Figure 3). We will discuss how we are developing and using ontologies to reason about what structures are adjacent to the path of injury so that we can predict the extent of organ damage.

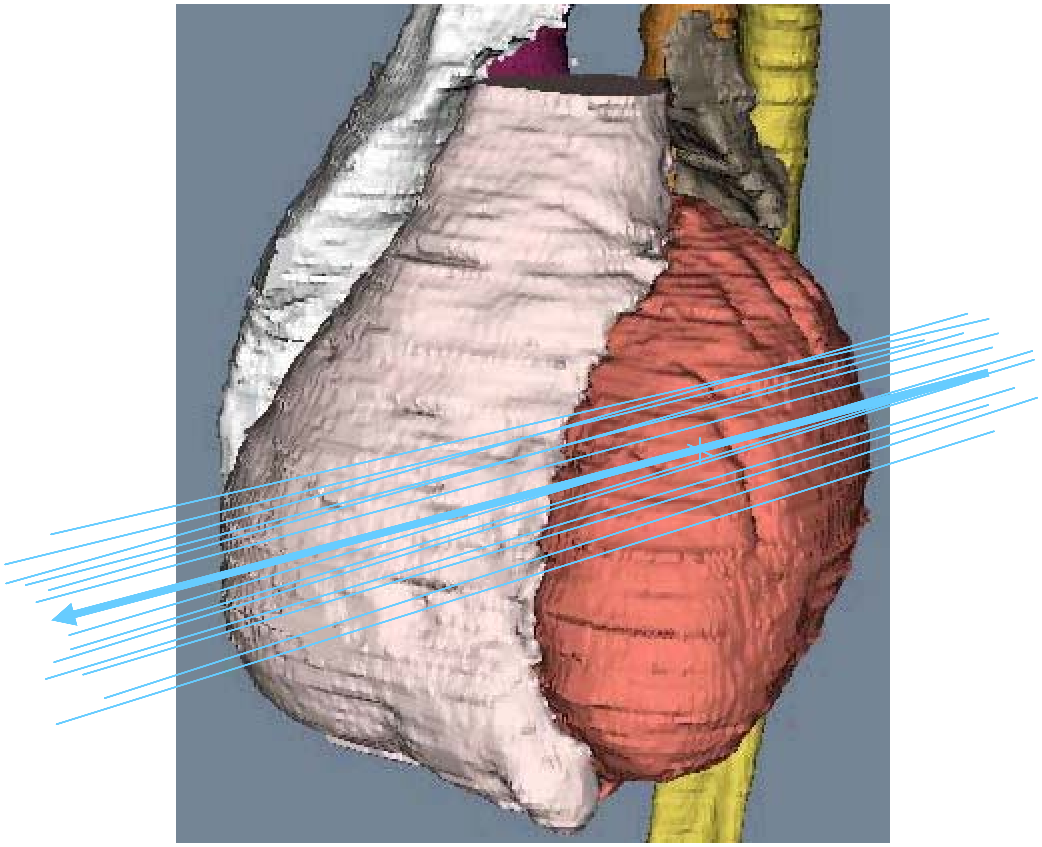

Figure 2: A geometrical model of the heart (surface –rendered display) with a superimposed hypothetical bullet trajectory (heavy arrow) surrounded by nearby regions of possible trajectories of tissue injury (thin lines).

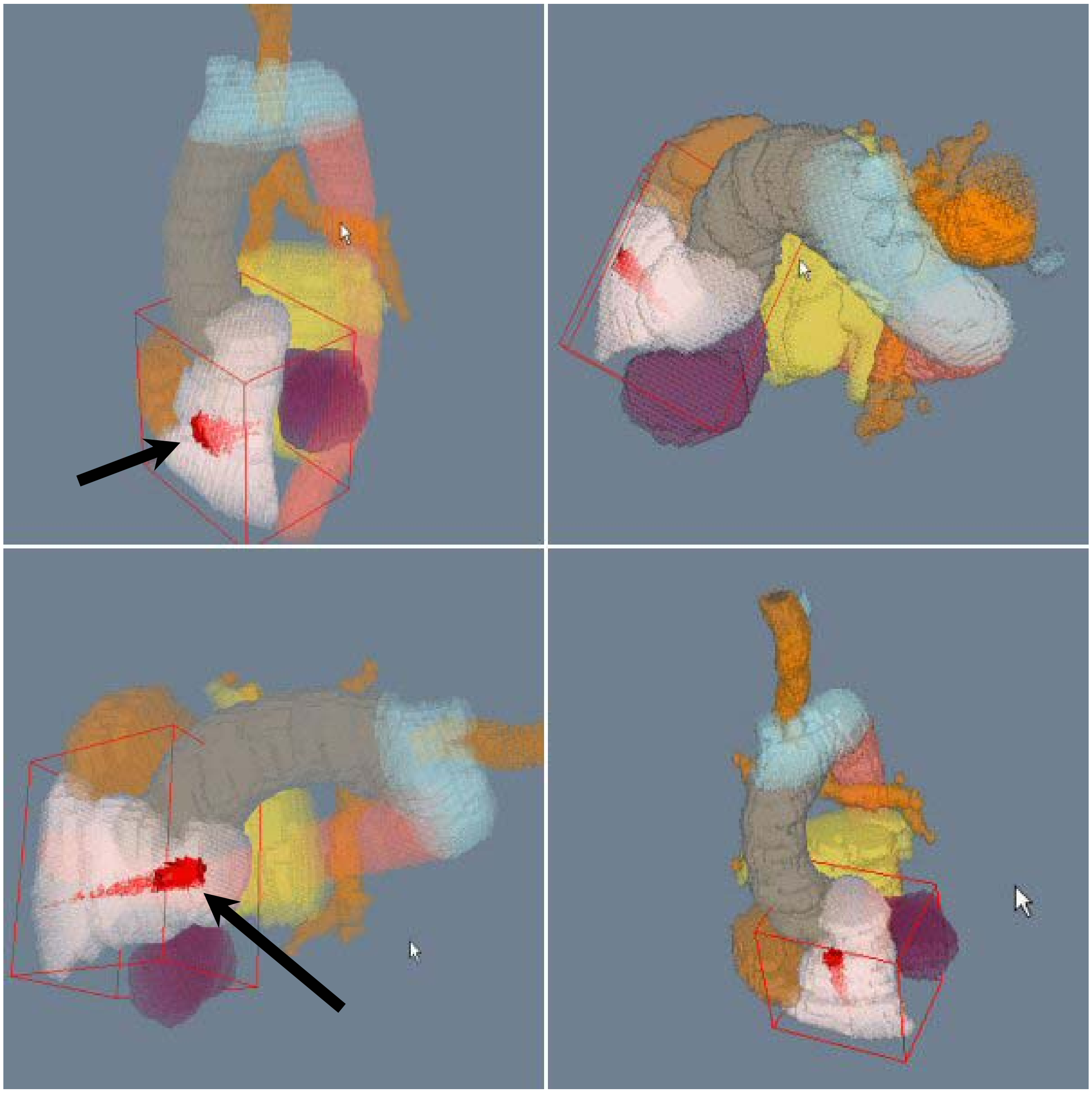

Figure 3: Four views of a three dimensional geometric model of the heart with anatomic structures labeled (shaded structures in the geometric model correspond to anatomic structure classes in the FMA ontology). A trajectory of penetrating injury was superimposed, and regions of tissue injury are predicted and demonstrated in the geometrical model (conical region shown by arrow). We can determine the identities of injured anatomic structures and infer the possibly injured adjacent structures using knowledge in the FMA ontology.

Issues we are working on:

- Canonical representations of geometry models
- Representation of geometry that permits linking of 3-d models to FMA anatomy ontology for efficient rendering as well as reasoning
- Storing ancillary information relevant to the problem domain, such as tissue biomechanics and tissue injury
- Interactive display of these geometrical models and user queries