1 Engineering the Proposed System

We propose to develop a system to visualize and measure the geometry of a patient's cervical spine using a combination of CT, MR and x-ray images. This system will assist surgeons in planning spinal surgery. In addition, this system will form a technical foundation for further advances in spinal modeling and patient evaluation. Figure 1a shows a block diagram of the proposed system. Figure 1b shows a block diagram of the segmenter.

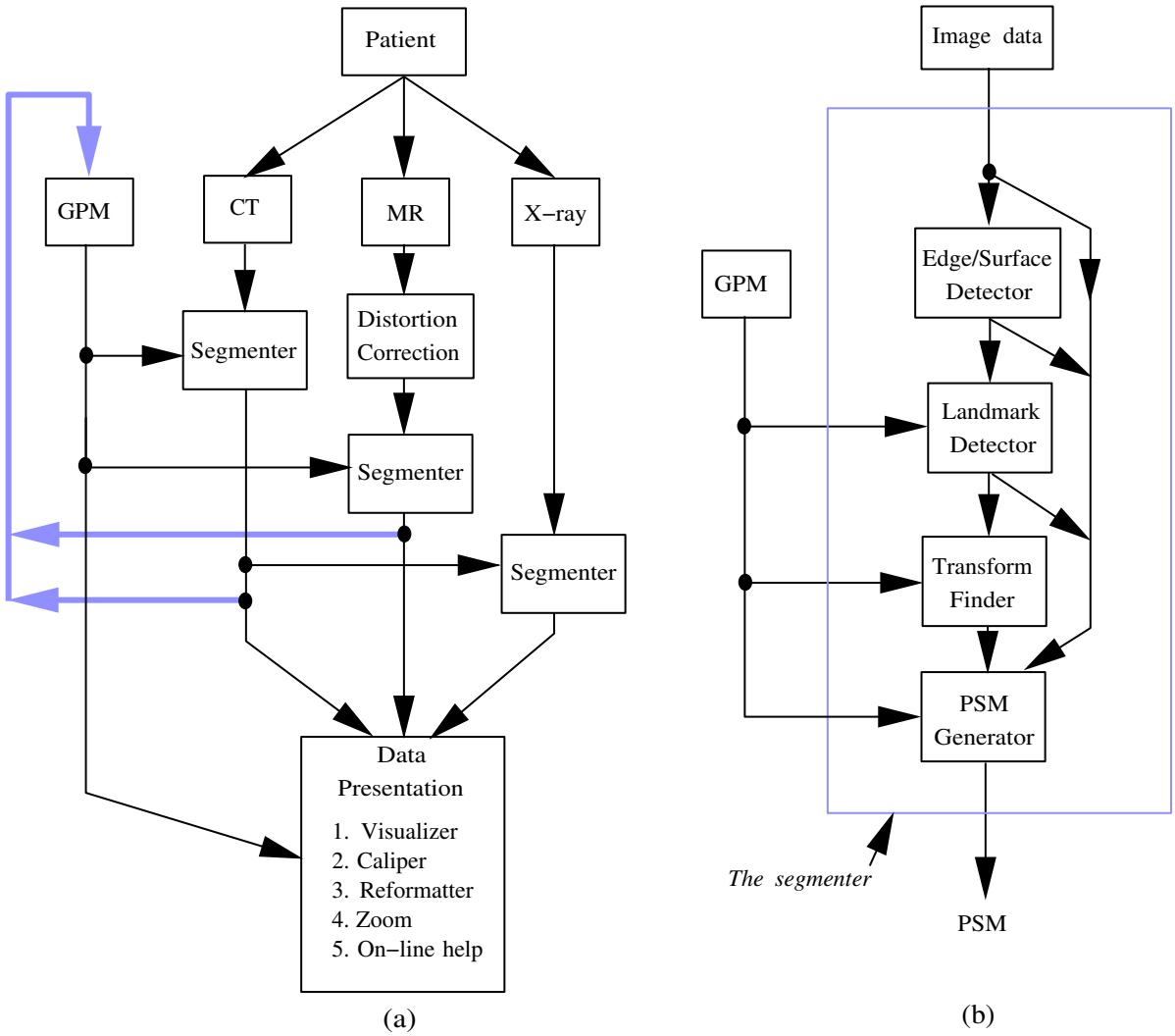

Figure 1: Block diagram of the proposed system.

The input to this system will consist of the patient's CT, MR and X-ray images. The output of the system will be interactive 3D visual representation of the patient's cervical spine. The surgeon will manipulate the display to optimally visualize a specific patient's spinal disorder and perform various measurements such as determining the diameter of the spinal column or the proximity of a nerve to a disc. The major components of the proposed system are the generic parametric model (GPM), MR distortion correction filter, 3D image segmentation and data presentation layers.

1.1 GPM

The GPM will be developed as a collection of parameterized solid models representing anatomic elements of the cervical spine (e.g. the vertebrae, discs, nerves and muscles). The parameters of this model will initially be limited to the shape descriptors of spinal elements. The GPM will contain a set of rules and parameterized transformations describing the spatial relationships between anatomic elements. The GPM will direct a search for landmarks within a dataset to automatically register CT, MR and X-ray images. It will also provide a basis for future work in developing a biomechanical model of the cervical spine. An original GPM will be constructed using several (i.e. more than ten) CT and MR imaging studies and will be continually updated as new patient data is acquired. In summary, the GPM constitutes the model we will be developing for a model-based segmentation strategy to assist in locating certain surface landmarks in both CT and MR images.

1.2 MR Distortion Correction

Meaningful image fusion can only be accomplished if the spatial relationships of one image are consistent with those of another image. The amount of geometric distortion in an image is a measure of the accuracy of these spatial relationships. Due to the nature of the imaging device, geometric distortion (on the order of several millimeters) is prevalent in MR images. [1]. The distortion in MR images must be removed to accurately map voxels from the CT to MR.

1.3 Segmenter

Using the GPM, the segmenter will convert the image data into a Patient Specific Model (PSM). The first step in the segmentation task is to accurately identify the boundaries of anatomic elements within a set of data (see figure 1b). We propose to extend our accurate boundary detector for 2D images to 3D images. It is anticipated that the boundary location accuracy will be one tenth of a millimeter and that the orientation accuracy will be within one degree. A subset of the detected boundaries representing a set of known landmarks will be identified using the GPM. These landmarks will include visible elements in the CT and MR images such as the edges of the discs or edges of the vertabrae. Landmarks will then be used to determine the transformation between image data and the GPM. Finally, using the GPM, an image-to-GPM transform, and the image data itself, the voxels corresponding to the anatomic elements of the patient's image data will be determined and used to compute the parameters of a PSM formed by the GPM.

1.4 Data Presentation

The surgeon will be presented with image data and a set of measuring tools. Many combinations and variations of the data will be available for a surgeon to make an accurate diagnosis and to plan the optimal interventional strategy. The surgeon will be able to interactively view, via image browsers and inspectors, the original or enhanced images, 3D representations of the individual studies or 3D representations of the fused image data. An oblique slicing plane to view any arbitrary 2D slice of the 3D volume will be provided. In addition to these

visualization tools, a set of measuring tools for determining the distance between specific 3D points will be provided. These distances will include both line-of-sight distance as well as curved trajectory measurements. Non-replicated pixel zooming for detailed investigation will also be developed.

A simple and meaningful interface will be provided to the surgeon to allow quick and easy access to the desired functions. The system will be tailored explicitly to the non-computer specialist and minimal training will be necessary to operate it.

References

[1] Thilaka Sudharman Sumanaweera. *Segmentation and Distortion Correction in Medical Imaging.* PhD thesis, Stanford University, Dept. of Electrical Engineering, Stanford, CA 94305, 1992.