Chapter 7

Conclusions and Future Directions

7.1 Thesis Summary

In human body, spine is a very complex mechanical structure that is highly flexible, strong and stable. It is a long, thin, tubular bundle of nervous tissue and it supports cells that extend from the brain. The brain and spinal cord together make up the central nervous system. Normal spine will have two curves in the PA direction. One at the lower region of cervical and other one is at lumbar region. Spine axis looks like a straight line in the PA view. Normal spine curves will be visible in the lateral direction. Spinal disorders are of different types, are listed in Chapter 2. Spine structural deformity in the lateral view is named as scoliosis. Scoliosis is a curvature of the spine in the lateral direction. It is a three dimensional deformity, needs three dimensional diagnosing information. Current 3D diagnosing systems are CT and MRI; both are discarded from the scoliosis diagnosing procedures because of heavy dosage, continuous evaluation, cost and posture. In order to avoid these problems SRS adopted radiographs as the diagnosing information. These radiographs are used to estimate spinal curvature and vertebral rotation. Further, detailed
analysis of disease is possible with King’s classification.

Spinal curvature is the angle between two highly deformed vertebrae. The degree of vertebral rotation is the deformity measurement in the transverse direction due to the displacement of pedicles. Both these techniques are well accepted in most of the diagnosing centers. Spinal curvature and vertebral rotation are based on the deformity of the vertebral body within the given radiographs and estimation needs human intervention. Chapter 2 lists different methods for quantification of spinal curvature and vertebral rotation. SRS adopted Cobb’s procedure for spinal curvature estimation and Nash-Moe technique for vertebral rotation as a standard method because of its better reproducibility, easier applicability and measurement of larger curvature in case of severe spinal disorders.

Spinal curvature as per Cobb’s definition needs identification of superior endplates as well as inferior end vertebral plates. Intersection of the lines along these end vertebral plates gives Cobb’s angle. Human intervention is mandatory for deciding end vertebral plates and marking. Due to human decision at different levels, inter- and intra-observer error variation is introduced. This error will mislead the treatment procedures and an improvement in the treatment may give wrong information due to diagnosing error. Similar error occurs in case of vertebral rotation, because of misidentification of apical vertebra and its pedicle position. Same problem is extended during scoliosis classification as per King’s definition while drawing CSL and medial axis line on the noisy radiographs.

Computer assisted systems are useful to eliminate these errors up to some extent. It works on digital reconstruction of manually identified anatomical landmarks. Computerized image processing system evaluates based on the enhanced or edge detected radiographs. Problem associated with this system is, it may enhance some unwanted information. This encourages us to use computerized image understating system for elimination of inter- and intra-
Conclusion and Future Directions

observer error during scoliotic parameter estimation. Chapter 4, 5 and 6 discussed our contribution to estimate spinal curvature, grading of apical vertebra and automatic classification of scoliotic radiograph as per King’s definition respectively.

7.2 Contributions of the thesis

1. Spinal curvature estimation: Estimation of spinal curvature depends on the most tilted vertebrae at the two extremities of the curve and curves may be single or double. In case of single, two end vertebral definitions are required, in case of double curve four end vertebral definition are required. Manual and computerized methods are based on human judgment about end vertebral plates. Computerized image understanding system eliminates these errors by extracting the features using image processing algorithms. Cobb angle calculation needs image features as vertebral horizontal endplates. The vertebral endplate extraction follows computerized algorithm for final decision. It is very difficult to extract only the horizontal endplates as features. First extract the whole vertebral boundary itself as features using active contour models. These extracted features are fed to the morphological processing system to retain only the required horizontal vertebral endplates. Once the horizontal end vertebral plates are extracted, the vertebral endplates are objectively represented using slope information calculated using Hough transform. Thus the proposed computerized image processing system completely automates quantification of scoliosis in terms of its spinal curvature.

2. Vertebra rotation estimation: The rotation deformity in scoliotic spine is represented by its highly deformed vertebra (i.e., apical verte-
bra). Apical vertebra is the vertebra which is displaced from its original position in the lateral direction. In case of manual and computer assisted procedures, the apical vertebra is defined by manual judgment. Any error introduced during selection of apical vertebra will propagate to next steps in the procedures. The proposed computerized image understanding method will support an automatic identification of apical vertebra. Once the slope information is ready (as explained in previous section), the decision about the apical vertebral is based on the polarity of the slope of the vertebrae. Then divide the apical vertebral body into six equal regions in the lateral view. The placement of the pedicles within these six segmented region will quantify the vertebral rotation as defined by Nash-Moe procedure.

3. **Automatic classification system:** Classification of a scoliosis is a study procedure to keep track of the frequency of occurrence of this disease with different severity. To classify scoliosis radiograph into any one of the defined category we should know the severity in terms of curvature deviation as well the region it has happened. As on today there exist many classification procedures. The King classification is the tendered one because of its simplicity as well as easy to classify into any one out of five different categories. Kings classification procedures are based on the deviation of the curves, number of curves, region of curves and which curve has highest defomity with what curve, all these are required information for the King’s classification procedures. A manual classification procedure depends on human decision about different curves and its location. Computerized system forms the central sacral line by manual marking of four points on the last lumbar vertebrae. Medial axis is defined by marking sixty eight points on the whole spine, with four points per vertebrae, which is very tedious and also time consuming.
The proposed computerized image understanding system, defines these
two axis automatically by extracting the whole spine boundary using
image processing steps. A gray level profile is used to extract the region
of interest. Exact segmentation of the vertebral column depends on the
interpolation method. Fast Fourier interpolation is used to get better
result compared to other interpolation. Once the vertebral column is ex-
tracted, the central sacral line as well as medial axis is defined. Medial
axis is the centroid of the extracted spine boundary. The medial axis is
determined by averaging the coordinates of the boundary points of the
extracted boundary in the horizontal direction. Automatically identified
medial axis and CSL lines are given to proposed classification procedures
which follows King’s definition of classification.

7.3 Future Directions

Developed image understanding method does automated quantification of spinal
curvature, vertebral rotation and classification as per King’s definition. Devel-
opment of this automated system is based on extraction of different features
like end vertebral plates, CSL, medial axis and pedicle displacement. These
features are even applicable to other set of spinal disorders like Kyphosis and
Lordosis, but in the lateral view. Kyphosis and Lorodosis are the 3D spine de-
formity in PA direction. The extraction of CSL and medial axis in the lateral
view makes automatic diagnosis of Kyphosis or Lordosis. Similarly, we can ex-
tend the use of these extracted features as end vertebral plates for diagnosing
of osteoporosis (vertebral body deformity due to aging).

Scoliosis is a 3D deformity and better analysis is possible by 3D bi-planar
reconstruction. The difficulty in finding stereo and non-stereo corresponding
points throws real challenge along with less number of stereo points. This
thesis proposed a technique for extraction of spine boundary, CSL and medial
axis in anteroposterior view and same can be extended to other lateral view. This will be useful in finding the stereo and non-stereo corresponding points automatically. Thereby more number of stereo corresponding points helps for better 3D reconstruction of scoliotic spine.