Abstract

Scoliosis is a three dimensional deformity of human spine comprising coronal plane curvature and axial rotation with maximal translation and rotation occurring at apex. It is one of the major skeletal diseases in adolescents. In majority of the cases, the cause is unknown (idiopathic). The progression of the disease occurs in three dimensions, with the spine simultaneously curving towards the arms and rotating as it collapses with the first indications usually being changes in body symmetry and back surface shape. Imaging modalities such as radiography, computed tomography (CT) and magnetic resonance imaging (MRI) play pivotal roles in the diagnosis, monitoring and management of the scoliosis with radiography having the primary role with MRI/CT.

In interpreting the imaging features of scoliosis from the radiograph, it is essential to identify the significance of vertebrae in or near the curved segment (apex, end vertebra, neutral vertebra, stable vertebra), the curve type (primary or secondary, structural or nonstructural), the degree of angulations (measured with the Cobb method), the degree of vertebral rotation (measured with the Nash-Moe method) and the longitudinal extent of spinal involvement (according to the classification system). The measurement of these parameters needs to be reliable and reproducible as the treatment of idiopathic scoliosis is governed by the severity of the initial curvature and the probability of progression. The detailed study revealed inter and intra observer errors caused by human intervention during quantification of these parameters. This thesis focuses on objective measurement of these parameters using image processing.

Severity of the spine curvature in the lateral view is quantified by Cobb angle. Quantification of Cobb angle is based on the identification of vertebral endplates as well as manual landmark identification with ruler and pencil. This thesis proposes a method for automatic identification of vertebral endplates by extracting the boundary of all vertebrae and angle calculation by slope inter-
cept form using image processing. Firstly, using non-linear filters noise present in the radiographs are removed without blurring the expected edges. Segmentation of vertebral boundary is done using active contour models, which results in complete morphometry of every vertebra. The vertical component of the boundary is removed by morphological operation with a designed structuring element. The slope of horizontal component calculated from Hough transform helps to decide the vertebral endplates. The slope intercept representation of these endplates are used for quantification of Cobb angle.

Scoliosis is a three dimensional deformity, only the spinal curvature is not sufficient to estimate the extent of severity. This can be used along with vertebral rotation in the lateral direction, which is usually measured using Nash-Moe technique. Objective estimation of vertebral rotation involves identification of apical vertebra (i.e., highly deformed vertebra) and pedicle displacement. This thesis automates the identification of apical vertebra and position of pedicle using image processing. Hence eliminates observer error in selecting the apical vertebra and tracing the pedicle boundary inside it. Further, identified apical vertebra is divided into six equal segments using the computer assisted method. The position of the pedicles within the segments is used to grade the vertebral rotation as per Nash-Moe’s definition.

Scoliosis curve pattern classification are used in surgical planning. A good classification system has to include different types of curve and should be a guide for surgical planning. Classification of scoliosis is helpful to decide about treatment and to evaluate severity of scoliosis. Classification procedures are based on the presence of curves in different regions of spine as well its associated curvature. State-of-the-art classification procedures are based on manual identification of the curves at different levels as well as its deviation. This thesis extracts spinal column from the entire radiograph using customized filter and thereby avoiding misclassification due to unwanted regions. The central sacral line as well as medial axis are automatically identified by the
extracted spinal column. Medial axis and central sacral line are fed as input to the developed rule based algorithm for automatic classification of scoliosis as per King’s definition. The extent of deviation of medial axis from the central sacral line will help to classify the given radiograph into one of the five types defined by King.

Quantitative evaluation of spinal curvature, automated grading of apical vertebral rotation and reliable measurement for longitudinal extent of spinal deformity are done by interpreting the required image features using image processing technique.

The entire thesis is organized into seven chapters, with initial three chapters covering introduction, background and problem formulation. Following are the three contributed chapters and conclusion with future scope.

**Keywords:** Scoliosis, Cobb angle, Vertebral rotation, King’s classification, Active Contour Models, Hough Transform, Level Set segmentation, Morphological operation, Boundary Descriptor