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Cobb Angle Measurement from Coronal X-Rays Using Artificial Neural Networks

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Abstract : Scoliosis is a complex 3D deformity of the thoracic and lumbar spines, clinically diagnosed by measurement of a Cobb angle of 10 degrees or more on a coronal X-ray. The Cobb angle is the angle made by the lines drawn along the proximal and distal endplates of the respective proximal and distal vertebrae comprising the curve. Traditionally, Cobb angles are measured manually using either a marker, straight edge, and protractor or image measurement software. The task of measuring the Cobb angle can also be represented by a function taking the spine geometry rendered using X-ray imaging as input and returning the approximate angle. Although the form of such a function may be unknown, it can be approximated using artificial neural networks (ANNs). The performance of ANNs is affected by many factors, including the choice of activation function and network architecture; however, the effects of these parameters on the accuracy of scoliotic deformity measurements are poorly understood. Therefore, the objective of this study was to systematically investigate the effect of ANN architecture and activation function on Cobb angle measurement from the coronal X-rays of scoliotic subjects. The data set for this study consisted of 609 coronal chest X-rays of scoliotic subjects divided into 481 training images and 128 test images. These data, which included labeled Cobb angle measurements, were obtained from the SpineWeb online database. In order to normalize the input data, each image was resized using bi-linear interpolation to a size of 500 × 187 pixels, and the pixel intensities were scaled to be between 0 and 1. A fully connected (dense) ANN with a fixed cost function (mean squared error), batch size (10), and learning rate (0.01) was developed using Python Version 3.7.3 and TensorFlow 1.13.1. The activation functions (sigmoid, hyperbolic tangent [tanh], or rectified linear units [ReLU]), number of hidden layers (1, 3, 5, or 10), and number of neurons per layer (10, 100, or 1000) were varied systematically to generate a total of 36 network conditions. Stochastic gradient descent with early stopping was used to train each network. Three trials were run per condition, and the final mean squared errors and mean absolute errors were averaged to quantify the network response for each condition. The network that performed the best used ReLU neurons had three hidden layers, and 100 neurons per layer. The average mean squared error of this network was 222.28 ± 30 degrees2, and the average mean absolute error was 11.96 ± 0.64 degrees. It is also notable that while most of the networks performed similarly, the networks using ReLU neurons, 10 hidden layers, and 1000 neurons per layer, and those using Tanh neurons, one hidden layer, and 10 neurons per layer performed markedly worse with average mean squared errors greater than 400 degrees2 and average mean absolute errors greater than 16 degrees. From the results of this study, it can be seen that the choice of ANN architecture and activation function has a clear impact on Cobb angle inference from coronal X-rays of scoliotic subjects.

Keywords : scoliosis, artificial neural networks, cobb angle, medical imaging
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