Low Cost Technology Alternative for Diagnosing Scoliosis Utilizing Computerized Technologies

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Abstract

Image of a scoliotic spine

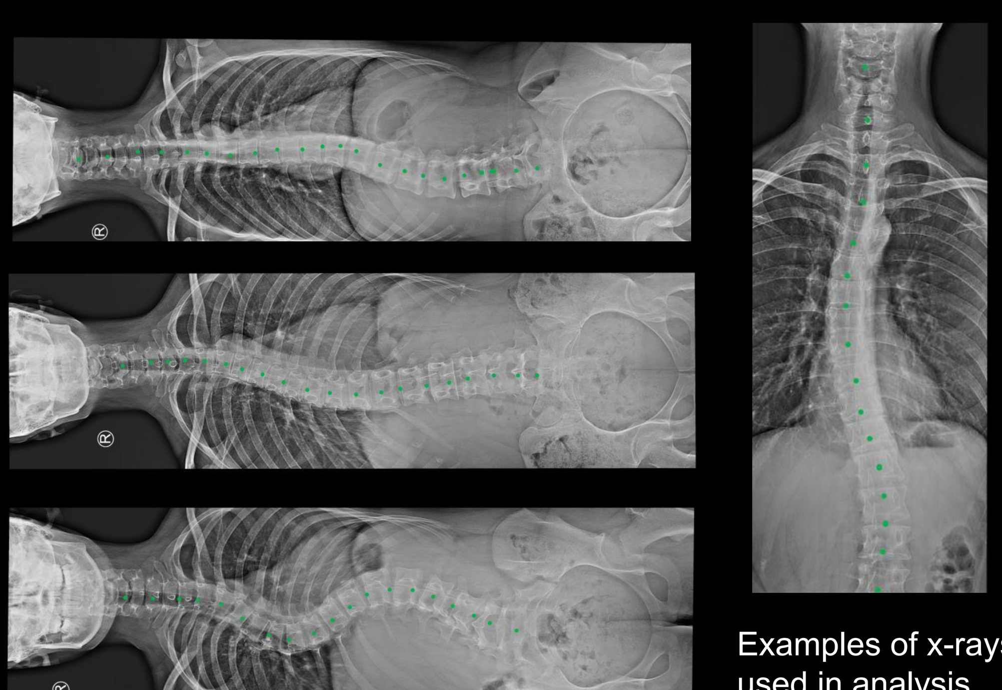
Scoliosis is a disorder defined by excessive lateral curvature of the spine. Diagnosis is traditionally accomplished by manually measuring the (Cobb) angle formed by endplates of the most tilted vertebrae on an x-ray of the patient's back. While this is a simple and effective method of diagnosis, it does have disadvantages. Using this method, there are often large variations in measurement between clinicians, patients are exposed to large doses of x-ray radiation in order to obtain images of sufficient resolution, and adequate equipment is not available in some parts of the world. AI programs trained to segment the spine and automate measurement of the Cobb angle have been proposed as a way to reduce measurement error and possibly reduce the need for high dose x-rays. We propose a screening method that will reduce the reliance on x-rays and minimize percent error between users; using markers along the patient's back, locating the spine through palpation, and approximating an angle similar to, but not exactly, the Cobb angle by extracting locations of the markers from a photograph of the patient's back using computer graphic and curve fitting techniques. After validating the implementation of the curve fitting software, our next goal is to build a phone app that can be safely and inexpensively used to screen for scoliosis.

Method: Testing Software Robustness

The software generated to screen for scoliosis collects its data through the recognition of specific color hues strategically placed along the vertebrae of the spine. From this, a curve can be generated that mimics the spine and an angle similar to the Cobb angle can be derived. For the initial testing of this program, we narrowed our focus to inputting x-rays that displayed spines with slight to severe cases of scoliosis, as the program performs equally as well when presented with a digital x-ray and an image of physical markers along a patient's spine. Ten x-rays were analyzed by four individuals, in which each was required to individually mark the vertebrae and run through the program to evaluate the robustness and consistency of the program. Each image was individually marked to account for any inconsistencies that may be present in the practical application of global-accessibility.

Results

After processing each image, the given results had an average standard deviation of 3.47 degrees and median standard deviation of 2.87 degrees. Images with clearer indications of scoliosis tended to have greater inconsistencies, whereas those with less obvious signs were more consistent. It is important to note that the region of the spine being analyzed significantly affected the results of these trials.



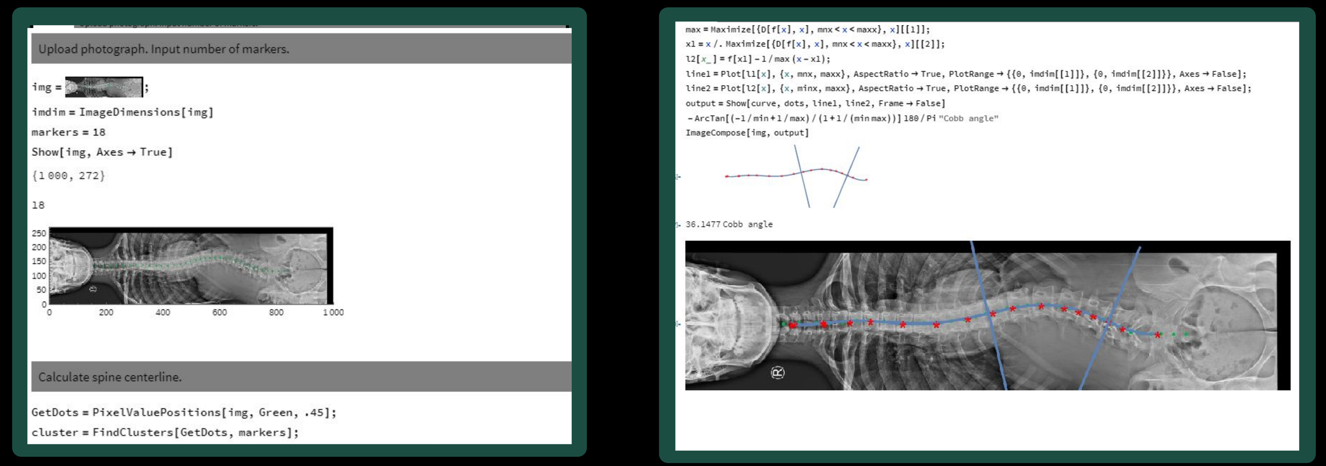
Examples of x-rays used in analysis

An Automated Method

An automated method using a Convolutional Neural Network to segment vertebrae in a digital x-ray scan has been proposed (Imran et al., 2020) that addresses several of the issues associated with the manual measurement of the Cobb angle. A trained neural network might reduce the possibility of human error, at the same time allowing the use of x-rays with less resolution thereby exposing the patient to lower doses of radiation. Human error through palpation is reported to be "29 to 71% [of inaccuracies] and for mean palpation error values have been reported varying 2.7 to 19.3 mm" (Severijns et al., 2021).

Proposed Method

We propose a method that mimics the measurement of the Cobb angle by representing the spine as a least squares polynomial curve $y = \sum_{n=1}^{k} a_n x^n$ where k is typically between 5 and 7 (to avoid overfitting). Normal lines are drawn at the points of inflection and the angles between these lines are measured giving an approximation to the traditional Cobb angle. This approach has been proposed by others for use on x-ray images, notably in (Bonanni, 2017), and in (Papaliodis et al., 2017) where a preliminary study has been made to validate the procedure. We have written a code in Mathematica that automates the computation of the Cobb angle from an image with markers placed along the spine. Our program works equally well with markers placed along the spine center line on a digital x-ray, or physical markers placed along a patient's spine.



Sample of code used to identify key points on the spine and calculate angle

Current Research

Our goal is to curate a cell phone app that allows for our program to be accessible world-wide. The program allows for a simple, quick, and high-accuracy result responsive to the individual using the program and that informs a user whether their spine shows signs of being scoliotic. If developed into a cell phone application, this program will allow for the screening and monitoring of scoliosis in parts of the world where proper equipment is unavailable. Our current work involves:

Developing a protocol to be followed to ensure consistent measurement between clinicians.

Studying the complex geometry of the spine in the context of approximating the Cobb angle using a photograph of the patient's back rather than an x-ray. For instance, how does axial rotation of vertebrae affect the measurement of the Cobb angle in both the traditional and polynomial fit methods of computing the Cobb angle.

Develop a cellular application that incorporates out program and produces reliable and consistent results.

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