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Identification and Classification of Scoliosis Using CNN And SVM Algorithms

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ABSTRACT

Scoliosis is one of the most common diseases that is thrown under the radar. The lateral curvature and rotation seen in the vertebrae of the spinal column is classified in mostly 2 types: C-Curve and S-Curve. People need to be aware of the early signs and symptoms so that it is diagnosed in the proper time and manner. Scoliosis is mostly diagnosed and identified by taking X-ray medical images of the spine and based on the sideways curvature image modality. In traditional scoliosis diagnosis detection, the treatment is based on spinal assessment which a manual study consisting of major limitations mainly is being very tedious, time-consuming, and cost effective. Till date, without the assistance of technology, scoliosis diagnosis has been a critical task in the beginning because it all depended on the patient history records or even the captured x-ray images of the patient. Hence to ease up the process and provide better treatment experience, our research work is focused on categorizing the type of scoliosis in an effective, accurate and reliable way. This is obtained by analyzing and processing the input X-ray images obtained from the datasets and even the patients suffering from scoliosis. To overcome the aforementioned limitations, we developed a point-based automated method at different regions of the spinal cord resulting in accurate results using the Convolutional Neural Network (CNN) algorithm and further compared it to Support Vector Machines (SVM) for better understanding.

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1. INTRODUCTION

The backbone is the most essential central support structure of human anatomy. The vertebrae, facet joints, intervertebral disks, spinal cord and nerves along with soft tissues make up this structure that healthily has 2 natural curves that functions to absorb shocks to the body and prevent injury to the spine [1]. The 33 small bones that are stacked, also called the vertebrae form the spinal canal. This spinal canal houses the spinal cord and nerves to protect them from physical injuries. A slippery connective tissue: cartilage is present in the Facet joints that allows these small bones to slide against each other. This allows an individual the ability to twist and turn, additionally providing flexibility and stability to the whole-body structure [2]. Intervertebral discs are flat, round cushions that sit between the vertebrae and act as the spine's shock absorbers. The spinal cord is a column of nerves that functions as the carrier of the electric signal messages generated by the brain to the muscles. Finally, the ligaments that connect the vertebrae to hold the spine in position [3-5].

The responsibility of assuring these essential functionalities of the human body is entirely assigned to the spine. Anything unnatural such as the abnormal curvature of the spine would completely throw off the balance functionality of the support system and affect the healthiness of the body [6-8]. Previous statistics have shown that 80% of the world population experience back pain at some point of their lifetime. This abnormal sideways curvature of the spine, known as Scoliosis, may not cause major pains but can lead to uneven shoulders and leg length. Mostly common in adolescence, but not limited to, it can affect people of any age resulting in 2% of the world population affected every year. Technically, scoliosis is diagnosed as a three-dimensional spinal disorder [9-12]. This 3D disorder of the spine is declared positive if the curvature angle in the coronal plane is measured greater than 10°. The Cobb angle illustrated in Figure 1 shows 70° of curvature which exceeds the 10° base value of negligence which has become a quantitative standard in the medical industry. Doctors are required to follow this industry standard for diagnosing and observing the symptoms of scoliosis patients. Figure 2(a) is a standard representation of a C-Shaped Curve and Figure 2(b) is a standard representation of a S-Shaped Curve.

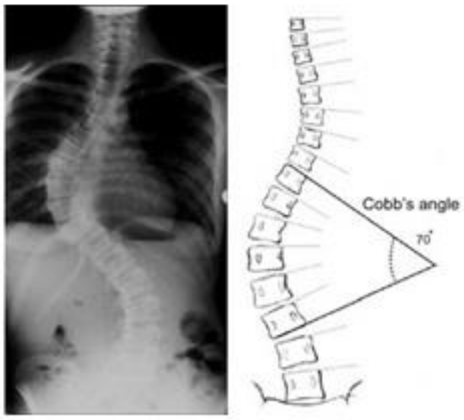

Figure 1: Cobb Angle Measurement

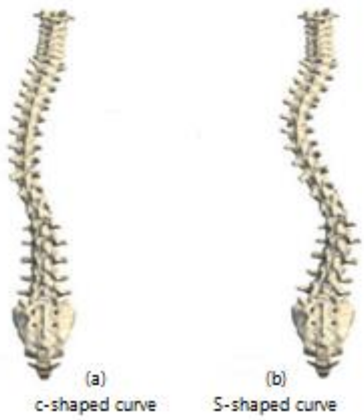

Figure 2: Types of Scoliosis

Using efficient and essential classification algorithms like these, predictive analysis is conducted, and the performance metrics are cross checked to benefit the patients to be diagnosed with scoliosis with minimum time, low cost and by improved quality of the input image [13-18]. The consistent and regular development of technology in the field of computer vision and image processing like machine learning target detection algorithms, the curvature is sharply detected that assists the algorithm to calculate the cobb angles. Till date, protractors are the goto tool for radiologists for measuring Cobb angle post manual selection of the end-vertebrae. Hence, the Cobb angle is never accurate because of the fact that the whole method mainly depended subjectively on the expertise and experience of radiologists [19-21]. Researchers who investigated the manually measured Cobb angles plotted deviations and they have deduced that the maximum margin of measurement error peaked at 11.8°[22]. This 11.8° of error margin is unacceptable to the point that it would result in false if not inaccurate diagnosis and treatment of scoliosis. Computer-aided methods are rather reliable and accurate comparatively to detect the curvature of the spine and to categorize the pattern of the curvature are urgently needed regardless of the degree of severity in terms of cobb angle. The authors [23-26] has proposed a method on the basis of Hough Transform which is computer-aided that automatically calculates Cobb angle. The end-vertebrae needs to be manually selected in the initial stage from the region of interest after which attributes of the images, such as brightness and contrast are tweaked for better clarity and processing. The author [27-29] proposed an alternate approach of segmentation algorithm where masking is done to the images to measure the Cobb angle. The authors [30] proposed an algorithm that automatically estimates the spinal slope from the block of interest which is manually selected in the upper and the lower vertebrae.

In this research project, we propose an automatic scoliosis detection and categorization algorithm based on deep learning.

2. LITERATURE SURVEY

After many practices the diagnosis and treatment is still difficult for scoliosis. Meanwhile, ML is used for the Scoliosis detection, diagnosis, screening, classification etc. The future with ML is going to be very bright [31-33]. Actually, ANNs has managed to obtain diagnosis, prognosis and outcome prediction for spine diseases [8]. There has been many applications of ML in problems related to the spine, including the localization of vertebrae and discs in radiological images, image segmentation etc but there are few issues related to use of AI and ML in healthcare, namely accountability, risk of biased decisions as well as data privacy and security which nowadays is a big issue [34]. It is also believed that diagnosis, prognosis and prediction in spinal diseases can be obtained by using ANNs which resulted in good practice in the medical field. Model using neural networks has been designed along with clinical data that can predict the spinal curve progression of a patient.[35]. In spine surgery the use of computer vision technology has greatly increased along with the use of computer assisted navigation, robot surgery etc all of which has a great level of exactness of 3D reconstruction of the spinal column. These all are achieved through automated segmentation via using ANNs. [36-39] The cobb angle or degree of scoliosis was attempted to be measure through bone feature segmentation from ultrasound spine images which is quite critical [40]. To overcome the noises produced in X-Ray images due to radiology was tried to overcome by filter method but this method affected the resolution of the image. Smoothing method was applied after filter method which could make the image clear, but a little imbalanced and thus adaptive trimmed mean filter was applied [41-43]. It was also aimed (to find the actual patient's spine features in various images caught up by optical cameras in an augmented reality surgical navigation (ARSN) system) / (to easily detect and match spinal features in multi-view stereo images, and to compare different feature detection algorithms) [44-47].

A new fuzzy filter is introduced for the noise reduction in the X-ray image of the scoliosis patients. The filter is being used recursively for the reduction of massive noise coming from the other parts of the body and In the end fuzzy filter is enough for the quick hardware implementations [48-50]. Detection of spondylosis using MRI scans were also done using image segmentation algorithms like PCA segmentation classifier image processing. Multiple picture segmentation approaches for processing the MRI images were done in order to analyze and detect Spondylosis in early stages.[51]. Machine Learning was used to detect the occurrences of Cardiac Arrest and used Synthetic Minority Oversampling Technique for data mining preprocessing to cope up Imbalance problems of the class as well as noise. The technique reduces the impact of data imbalance in the initial phase and classifies data. The AdaBoost Ensemble model uses recognized feature patterns for heart disease prediction [52-55]. Data Mining was used to improve success rate of IVF by performing pre-processing, normalization and data reduction using Feed Forward Neural Network based classification algorithm. [56-59]

3. PROPOSED METHODOLOGY

Detecting a curvature in the spinal cord is a challenging task. Medical imaging such as X-rays contain ample amounts of noise. Filtering out this noise and mapping the cobb angles precisely takes up a lot of image pre-processing [60].

To implement our model to detect the early-stage scoliosis with convolutional neural network (CNN) and Support vector Machine (SVM) with better accuracy and the user just need to upload the X – ray of spinal cord image and the model will detect the category with a fraction of time.

This system is a better approach for Scoliosis identification with higher accuracy.

The below Figure 3 is a detailed block diagram of our proposed system architecture which is elaborated below in 5 stages.

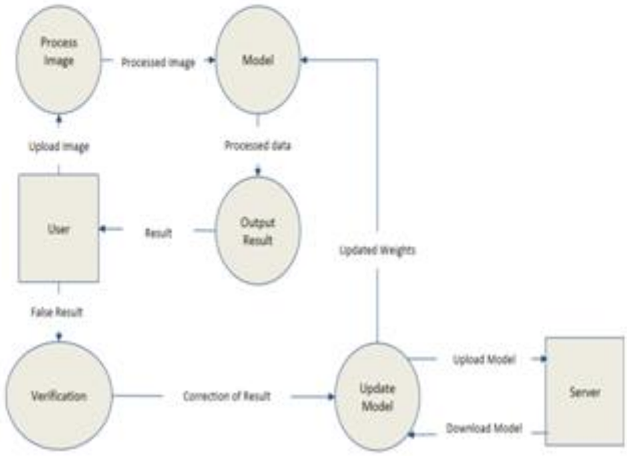

Figure 3. System Architecture

- Stage 1 – Input Image: The user/tester fetches the available X-ray medical images to the system that may or may not be of a patient diagnosed from scoliosis. These training datasets are collected from sources like Kaggle and GitHub.

- Stage 2 – Pre-processing: The training datasets from stage 1 are further sent for pre-processing before it is fed to Machine learning algorithms. Blurred, or noisy input X-ray images are common that require to be rectified or be removed. Therefore, such input images are mandatorily preprocessed to significantly speed up the training process.

- Stage 3 – Training and Testing: The collected dataset are split into 2 files. One for training purposes which amounts to 70% and the remaining 30% for testing purposes to be carried out for predictive analysis.

- Stage 4 - Classification methods: Convolutional Neural Network and Support Vector Machine (SVM) are one of the many machine learning algorithms that are widely used for classifying image datasets. The exact same datasets are trained and tested using both the algorithms separately to detect and categorize the type of scoliosis.

- Stage 5 – Performance Metrics: Accuracy (A), Elapsed Time (ET) and Loss are the few metrics focused to monitor the progress and result of the system individually and further compare the performance of each algorithm.

4. SCOLIOSIS DETECTION/ CATEGORIZATION: (WORKING AND ALGORITHM)

The main objective is to identify the category of scoliosis by analyzing the input image. Although Scoliosis classification can be done manually by domain experts, with growing amounts of data, this rapidly becomes a tedious and time-consuming process. Sometimes even the experts make mistakes in identifying the scoliosis category. Therefore, the research is driven in such a way the trained model will identify the category of the scoliosis immediately the user uploads the test X-ray image data. The two approaches: CNN and SVM, the models were trained separately side by side and tested.

a. Convolutional Neural Network (CNN): A convolutional neural network is defined as a feed-forward neural network that is generally used to analyze visual images by processing data with grid-like topology. A convolutional neural network is used to detect and classify objects in an image.

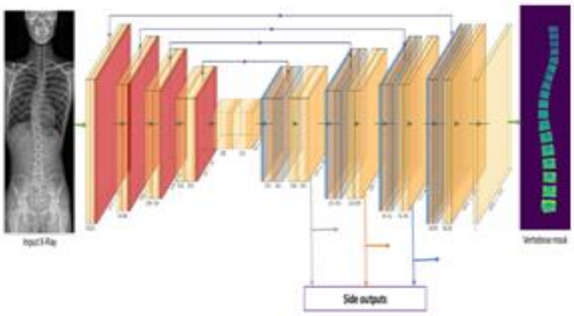

Figure 4: Convolutional Neural Network (CNN)

Figure 4. is a representation of application of CNN algorithm to detect and classify spinal cord medical images into scoliosis and its types. The first building block in the plan of attack is convolution operation which is shown in Figure 5 below. In this step, it is focused on feature detectors, which basically serve as the neural network's filters. Feature maps are plotted to learn the parameters and detect the patterns layer by layer ultimately assisting to map out the findings.

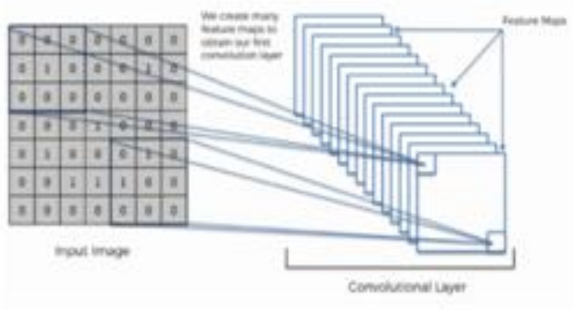

Figure 5. Convolutional Operation

After the feature extraction is done, we work on the Rectified Linear Unit to scan the images and separate the spine from background noise. Further image processing is done to get better accuracy and results like max pooling and flattening. Max pooling does all the calculation of the maximum value for patches of a feature map. The resulting values are then used to create a down sampled (pooled) feature map. These pooled layers are then transitioned to flattened layers as these data are to be inserted into the neural network later on. This is all finally stitched together to be known as full connection.

b. Support Vector Machine (SVM): The objective of the support vector machine algorithm is to find a hyperplane in an N-dimensional space (N — the number of features) that distinctly classifies the data points.

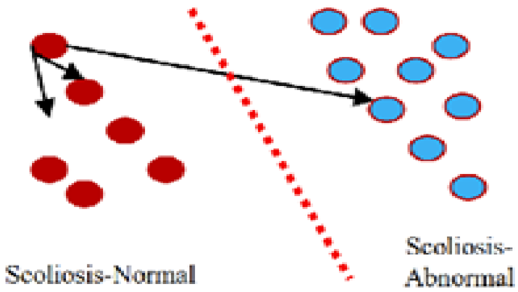

Figure 6. SVM algorithm for detection of scoliosis- normal and abnormal outcome

Figure 6 shows the difference between the support vectors of normal scoliosis to that of abnormal scoliosis. Support vectors are data points that are closer to the hyperplane and influence the position and orientation of the hyperplane. These support vectors are used to maximize the margin of the classifier.

Deleting the support vectors will change the position of the hyperplane. These are the points that help us build our SVM.

$$\frac{\delta}{\delta w_k}\lambda \parallel w \parallel^2 \quad = 2\lambda w_k$$

$$\frac{\delta}{\delta w_k}\left(1 - y_i\langle x_i, w\rangle\right)_+ \quad = \begin{cases} 0, & \text{if } y_i\langle x_i, w\rangle \geq 1 \\ -y_i x_{ik}, & \text{else} \end{cases}$$

Loss(x) SoftmaxLoss( )+1-Dice(x) = x

As shown in the above formula, the Dice coefficient is used to measure the difference between the prediction results and the labels during training.

Table 1. Test Cases Model Building

	Test Cases	*I/O*	*Expected O/T*	*Actual O/T*	*P/F*
1	Read the dataset	Dataset path	Dataset needs to be read successfully.	Dataset fetched successfully.	P
2	Performing preprocessing on the dataset	Pre-processing part takes place	Pre-processing should be performed on dataset	Pre-processing successfully completed.	P
3	Model Building	Model building for the clean data	Need to create model using required algorithms	Model Created Successfully.	P
4	Classification	Input image provided	Output should be the types of plant species	Model classified successfully	P

Table 1 illustrates the different phases the test cases are tested through the training model. Firstly, the dataset is fetched in as input where the expected output was to read the dataset successfully. The actual output resulted in positive fetching of the dataset successfully as expected. Similarly, the second test case was to perform pre-processing on the dataset. Pre-processing path takes place as input and the expected output is achieved. Likewise, for test cases: model building and classification, respective input of clean data and image were tested to achieve positive results that successfully created and classified the model to detect the type of the scoliosis of the patient.

5. EXPERIMENTAL RESULTS AND ANALYSIS

The required dataset is tailored from various sources and platforms such as GitHub and Kaggle. 70% of those were utilized for training and the rest 30% for testing. On top of that real time user data input was also tried and tested. The dataset is labeled accordingly for the categorization of the c-curve and s-curve.

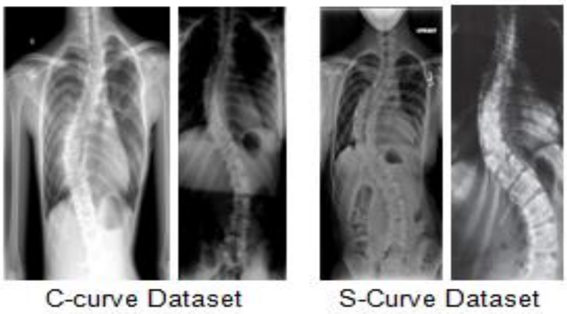

Figure 7. Training Dataset

Figure 7 are examples of the datasets that have been used to train the model of the categorisation of the scoliosis.

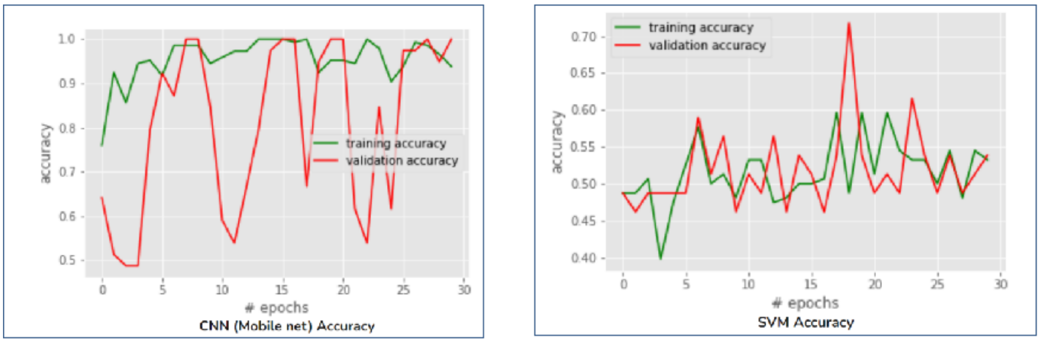

Figure 8. Comparison of accuracies acquired of CNN and SVM algorithms

The final phase of the project consists of a user interface that allows users to upload x-ray images. The system then detects the category of scoliosis: S-curve or C-curve. A separate tab is assigned where the accuracy of both the algorithms: CNN and SVM are illustrated as a graph. CNN: 90% or higher; and SVM: 45% till 60% has been achieved and illustrated.

CONCLUSION

Our research has concluded with facts and figures that the CNN algorithm is the best approach for implementing technology to detect Scoliosis. Studying and implementing all these knowledge and techniques in this research work has been insightful and discovery. This system is capable enough to kickstart the necessary measures and treatment on all kinds of scoliosis related problems. Monitoring the early signs and symptoms will result to be essential to the medical field stuck with the old traditional method of radiology. In contrast to this historical process where the result is neither accurate nor reliable because of the unnecessary lengthy process of screening, this system has achieved 90% plus accuracy through CNN and 60% plus accuracy on SVM. Narrowing this gap will take more of image processing, feature extraction and quality datasets.

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