DE-40 (DC&SE)

NUST COLLEGE OF

ELECTRICAL AND MECHANICAL ENGINEERING

Spinal Image Analysis To Find Cobb Angle and Automated Report Generation

A PROJECT REPORT

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Submitted by

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BACHELOR'S IN COMPUTER ENGINEERING

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PROJECT SUPERVISOR

DR. USMAN AKRAM

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PESHAWAR ROAD, RAWALPINDI

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We hereby declare that no portion of the work referred to in this Project Thesis has been submitted in support of an application for any other degree or qualification of this for any other university. If any act of plagiarism found, we are fully responsible for every disciplinary action taken against us depending upon the seriousness of the proven offence.

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ACKNOWLEDGEMENTS

Firstly, Alhamdulillah, that our FYP is finally made and all Thanks to Allah for giving us the strength and moral to keep pushing forward and helping us on every step of the way.

Secondly, we would like to offer heartily thanks our supervisors, Dr. Usman Akram, and Dr. Sajid Gul Khawaja, who helped us a lot, tremendously, on every single issue, who’s help, and guidance became a source of strong determination for us. Thank You, sir`s you played a great role in our lives, one that we can never forget.

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ABSTRACT

Correct diagnosis and treatment of scoliosis necessitate precise measurement of spinal curvature. Manually estimating Cobb Angles in spinal X-ray images is the current gold standard, however it is time consuming and has a high inter-rater variability. We offer an automatic method based on a unique framework that recognises vertebrae as objects first, then uses a landmark detector to estimate each vertebra's four landmark corners separately. Cobb Angles are calculated by taking the slope of each vertebra from the expected landmarks and multiplying it by the number of vertebrae. We perform pre and post processing on test data for inference, including cropping, outlier rejection, and smoothing of predicted landmarks.

The actor or any person using the app would first need to open the application on a web browser. For uploading an X ray image. First the image should be well light. For that there is a system to do necessary process to get best quality of image. After that User can upload the image to get the detail report of the medical image.

Image can be upload using the upload image button inside the app. After pressing the button, the user will be given an option to choose file from directory or folder. And then user will press ok button to upload the image to web application.

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CHAPTER 1: INTRODUCTION

Bones, joints, ligaments, and muscles make up the back, which is a sophisticated structure. Ligaments can be sprained, muscles can be strained, discs can be ruptured, and joints can be irritated, all of which can cause back discomfort. While sports injuries or accidents can cause back discomfort, even the simplest activities can be unpleasant, such as picking up a pencil from the floor. Back pain can also be caused or aggravated by arthritis, bad posture, obesity, and psychological stress. Back pain can also be caused by internal organ problems, such as kidney stones, kidney infections, blood clots, or bone loss. [1]

Back pain is the most common cause of disability worldwide, prohibiting many employees from working or participating in other daily activities. [2]

- According to experts, up to 80% of the population will suffer from back discomfort at some point in their lives.
- People of all ages, from teens to the elderly, can suffer from back discomfort.
- After skin illnesses and osteoarthritis/joint disorders, back discomfort is the third most common reason for doctor visits.

Back pain is one of the most common concerns that individuals make to their doctors. Nearly 65 million Americans have had recent back discomfort. Persistent or chronic back pain affects 16 million adults, or 8% of the population, limiting their ability to engage in various daily activities. In the United States, back pain is the sixth most expensive condition.

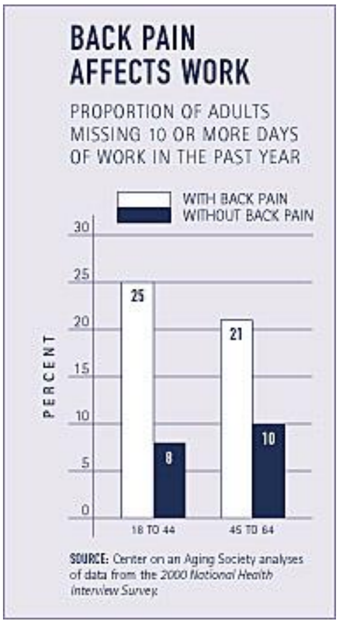

Figure 1 Proportion of adult missing workdays

The third most common reason for healthcare appointments is back pain. Between 1990 and 2015, the number of people disabled by low back pain climbed by 54%. Every year, Americans spend at least $50 billion on health care due to low back discomfort.

MRI scans of the lumbar area increased by more than 300 percent in Medicare beneficiaries from 1994 to 2005.

According to research issued by the World Health Organization in 2013, between 250 000 and 500 000 people worldwide suffer from spinal cord injuries each year (SCI).[3]

Third-world countries, such as Pakistan, require such research to be encouraged because our country's doctor-to-patient ratio is quite poor. In Pakistan, there are 1.5 competent neurologists for every 1.5 million individuals.

Because our institutes do not do active research in biomedical applications. For differential diagnosis of postural disorders, we need a trustworthy diagnostic method.

1.1 MOTIVATION

The research was applied to the development of an application that may be used in the medical field.

• There is a low doctor-to-patient ratio.

• Pakistan has only 120 competent neurologists for a population of 180 million people.

• In Pakistani educational institutes, there is a lack of an environment conducive to active biomedical research.

• Because there is a lack of a reliable computer-aided diagnostic technique for diagnosing and analyzing posture difficulties, this research is applied in nature, with the goal of developing an application that may be adopted by the medical industry.

Hence, a fully automated system that uses image processing and machine learning approaches to supplement the clinician's manual diagnosis of postural spine disorders is needed. A timely identification of spinal abnormalities can help to prevent paralysis for the rest of one's life.

1.2 SPINE ANATOMY

Spine performs a variety of important roles for humans, including supporting the body's weight and protecting the spinal cord and nerves. The spine is made up of 33 vertebrae that are split into five regions: cervical (C1–C7), thoracic (T1–T12), lumbar (L1–L5), sacrum (S1–S5), and coccyx (Co1–Co4). The upper 24 vertebrae are divided and moveable, offering flexibility to the spinal column. After puberty, the bottom 9 vertebrae are fixed, and 5 sacral vertebrae fuse to form the sacrum, and 4 coccygeal vertebrae fuse to form the coccyx. When viewed from the front, a typical spine should be straight and centered above the pelvis. [4]

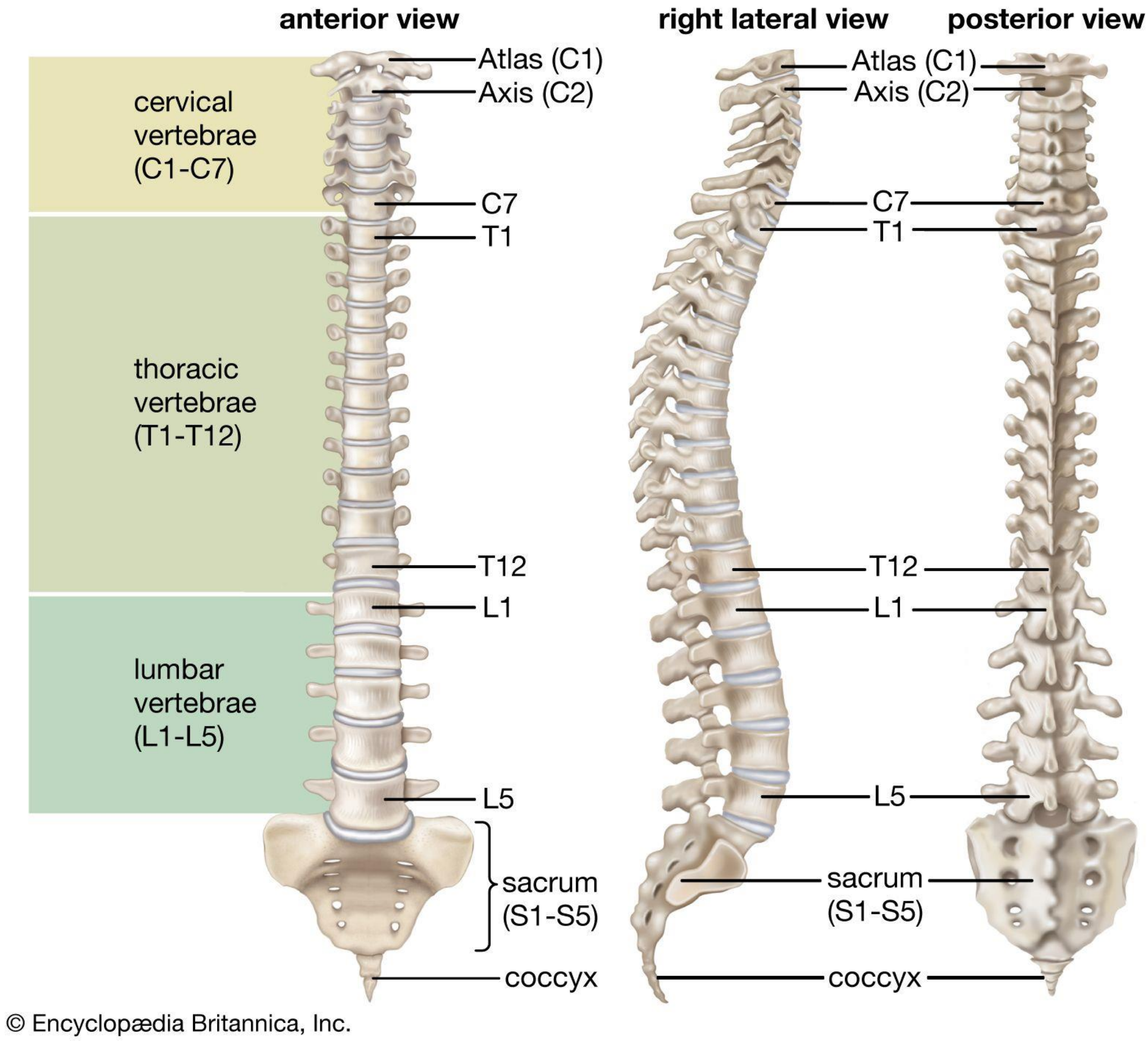

Figure 2 Spine Anatomy [5]

CHAPTER 2: SCOLIOSIS

Scoliosis is an abnormal lateral curvature of the spine. It is most often diagnosed in childhood or early adolescence. The spine's **normal curves** occur at the cervical, thoracic and lumbar regions in the so-called "sagittal" plane. These natural curves position the head over the pelvis and work as shock absorbers to distribute mechanical stress during movement. [6]

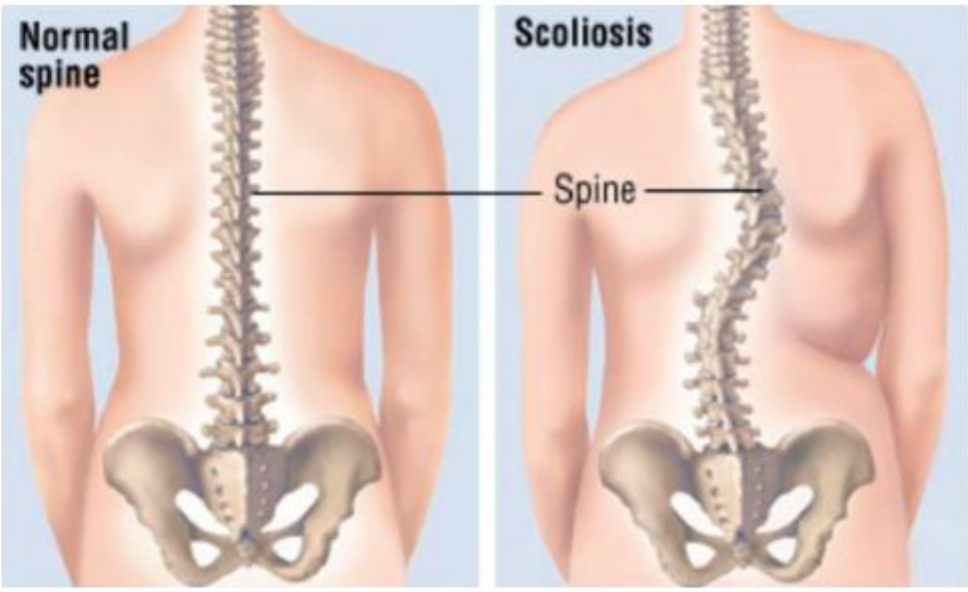

Figure 3 Normal and effected spine [7]

Scoliosis is characterised by a curvature of the spine in the "coronal" (frontal) plane. While the degree of curvature is determined in the coronal plane, scoliosis is a three-dimensional problem involving the following planes:

- **Coronal plane**
- **Sagittal plane**
- **Axial plane**

The coronal plane divides the body into anterior (front) and posterior (back) parts by running vertically from head to foot and parallel to the shoulders. The sagittal plane separates the right and left halves of the body. The axial plane is perpendicular to the ground plane and perpendicular to the coronal and sagittal planes.

In the United States, scoliosis affects 2% to 3% of the population, or approximately six to nine million people. Scoliosis can occur during childhood or infancy. Scoliosis, on the other hand, usually begins between the ages of 10 and 15, and affects both men and women equally.

Females are eight times more likely than males to reach a treatment-required curve magnitude. Scoliosis patients visit over 600,000 private physician offices each year, with an estimated 30,000 youngsters receiving a brace and 38,000 patients undergoing spinal fusion surgery.

2.1 Causes of Scoliosis

Idiopathic, congenital, and neuromuscular scoliosis are the three types of scoliosis. When all other reasons have been ruled out, idiopathic scoliosis is diagnosed, which accounts for around 80% of all instances. The most prevalent kind of scoliosis is adolescent idiopathic scoliosis, which is usually diagnosed during puberty.

Congenital scoliosis: It is caused by an embryological abnormality of one or more vertebrae, and it can affect any part of the spine. Because one section of the spinal column lengthens at a slower rate than the rest, vertebral anomalies induce curvature and other deformities. The rate at which the scoliosis increases in magnitude as the child grows is determined by the geometry and placement of the anomalies. Congenital scoliosis is frequently identified at a younger age than idiopathic scoliosis since these abnormalities are evident at birth.

Neuromuscular scoliosis: It includes scoliosis that develops as a result of neurological or muscular disorders. Scoliosis caused by cerebral palsy, spinal cord damage, muscular dystrophy, spinal muscular atrophy, and spina bifida are all examples of this. This type of scoliosis progresses more quickly than idiopathic scoliosis and frequently necessitates surgical intervention.

2.2 Symptoms and signs

Scoliosis can manifest itself in a variety of ways. One should make an appointment with a doctor if you detect one or more of the following symptoms.

- Shoulders are uneven – one or both shoulder blades may stick out
- Head is not centred directly above the pelvis
- One or both hips are raised or unusually high
- Rib cages are at different heights
- Waist is uneven
- The appearance or texture of the skin overlying the spine changes (dimples, hairy patches, colour abnormalities)
- The entire body leans to one side

According to one study, roughly 23% of people with idiopathic scoliosis had back pain when they were first diagnosed. A underlying ailment such as spondylolisthesis, syringomyelia, tethered cord, herniated disc, or spinal malignancy was discovered in 10% of these patients. If a patient with idiopathic scoliosis is experiencing more than minor back pain, a complete examination for another cause of pain is recommended.

Idiopathic scoliosis can compromise pulmonary function due to changes in the form and size of the thorax. Recent studies of pulmonary function tests in people with mild to moderate idiopathic scoliosis found that their lungs were impaired.

2.3 Diagnosis

A physical examination, x-ray, spinal radiograph, CT scan, or MRI are commonly used to confirm scoliosis. The Cobb Method is used to determine the severity of the curve, which is determined by the number of degrees. A coronal curvature of greater than 10 degrees assessed on a posterior-anterior radiograph is used to confirm a positive diagnosis of scoliosis. If a curve is greater than 25 to 30 degrees, it is considered substantial. Curves that are more than 45 degrees to 50 degrees are considered severe and sometimes necessitate more extensive therapy.

The Adam's Forward Bend Test is a routine assessment that is sometimes used by physicians and in grade school screenings. The patient leans forward with his or her feet together and bends his or her waist 90 degrees throughout this examination. Any asymmetry of the trunk or aberrant spinal curvatures can be easily recognized by the examiner at this perspective. This is a simple first screening test that can uncover potential issues, but it cannot precisely define the type or severity of the abnormality. For a precise and definite diagnosis, radiographic examinations are required.

X-ray: The structure of the vertebrae and the contour of the joints can be seen using an X-ray, which uses radiation to create a film or picture of a region of the body. X-rays of the spine are taken to rule out other reasons of pain, such as infections, fractures, and abnormalities.

Computed tomography scan (CT or CAT scan): A diagnostic image formed when a computer reads X-rays that can depict the shape and size of the spinal canal, its contents, and the structures around it is called a computed tomography scan (CT or CAT scan). Visualizes bone structures quite well.

- **Magnetic resonance imaging (MRI)** : It is a diagnostic technique that uses powerful magnets and computer technology to create three-dimensional images of human components. It can show the spinal cord, nerve roots, and surrounding areas, as well as enlargement, degeneration, and abnormalities.

CHAPTER 3: Conventional Method of COBB Angle estimation and Calculation

A physician uses imaging studies including X-rays, CT scans, and MRIs to determine the degree of spinal curvature and diagnose scoliosis. The Cobb angle, which was proposed by American orthopaedic surgeon John Robert Cobb and was adopted as the standard quantification of scoliosis by the Scoliosis Research Society (SRS) in 1966, is the most popular way to measure scoliosis. [8]

Manual measurement of Cobb Angles in anterior-posterior (AP) or lateral (LAT) X-ray images, which involves identifying the most tilted vertebrae above and below the peak of the spinal curve, is the current gold standard for diagnosing scoliosis. However, because the technique is time-consuming and observer-dependent, there is a lot of inter-observer variability, which might affect prognosis and treatment decisions. As a result, there has been a growing interest in estimating Cobb angles automatically from X-ray pictures

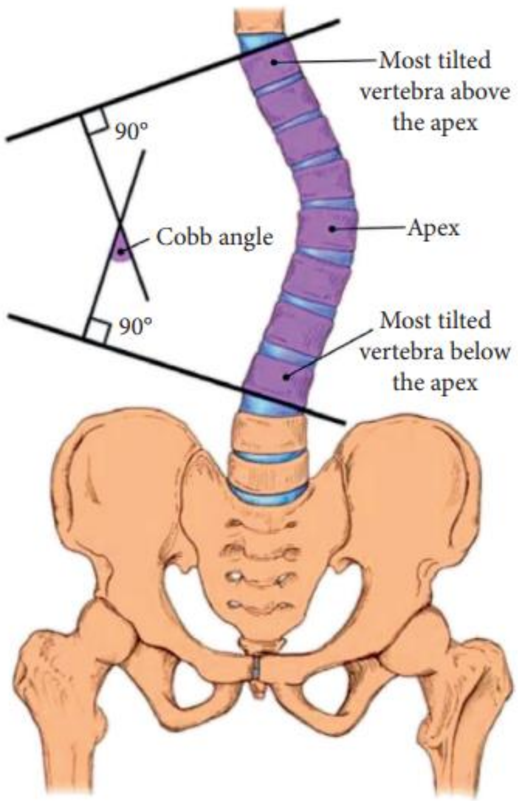

Figure 4 Calculation of Cobb Angle

The Cobb angle is used to determine the severity of scoliosis, as illustrated in Table 1. When the Cobb angle is less than 10 degrees, the condition of the spine is related with the spinal curve rather than scoliosis. Mild scoliosis is defined as a Cobb angle between 10 and 20 degrees. When the Cobb angle is between 20 and 40 degrees, the severity of scoliosis is moderate. Severe scoliosis is declared as a Cobb angle exceeds 40 degrees. [9]

Cobb angle	Definition
0°–10°	Spinal curve
10°–20°	Mild scoliosis
20°–40°	Moderate scoliosis
$>40^{\circ}$	Severe scoliosis

Table 1 – Classes of Scoliosis

There are three types of spinal deformity. The first is scoliosis, which is shown in an anterior-posterior view. The malformation is divided into two C and S shapes. The letter represents the pattern in spine curve, as the name implies. The C deformity has a single bend, while the S deformity has two convex sides, making the class more suitable for scoliosis patients.

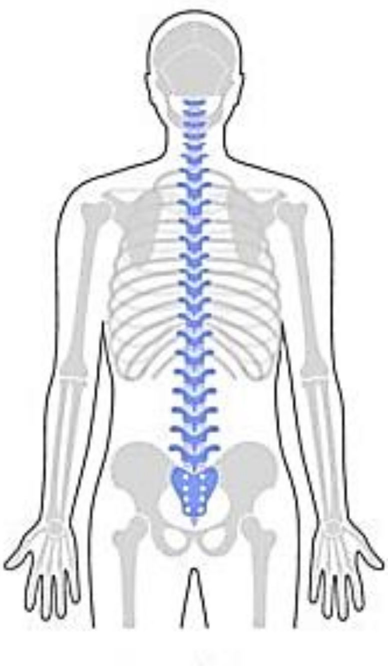

Figure 5 Normal Spine [10]

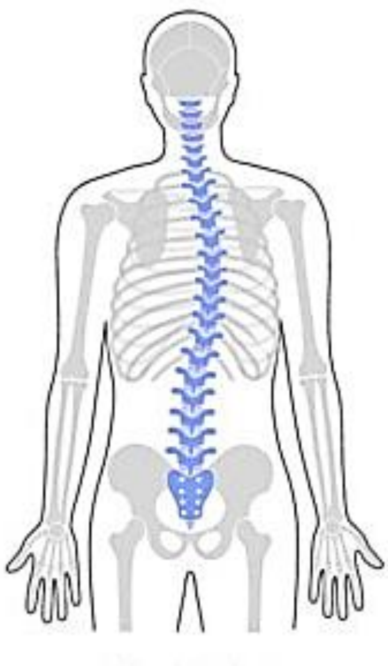

Figure 6 C-shaped Scoliosis [11]

Figure 7 S-shaped Scoliosis [12]

CHAPTER 4: Dataset

The collection contains 609 AP x-ray images of the spine and is available as Dataset 16 on SpineWeb 5. There are 68 GT landmarks in each image, corresponding to four corners of the 17 vertebrae and three Cobb Angles. Test photos sans GT were provided separately by the organisers. To generate GT boundary boxes, we joined the four landmark corners of each spine to form a box, which was then symmetrically expanded in width and height by 50 and 10 pixels. All of the bounding boxes were assigned to a single class. Individual vertebrae were cropped and extracted as a single distinct image having four landmark corners using the GT bounding boxes. The landmarks' coordinates are normalized to the coordinate system that maps all of the image's pixel coordinates. [13]

4.1 Dataset Gathering

Dataset could be an amassment of different sorts of information put away in a advanced organize. Information is the key component of any Machine Learning elongate. Datasets essentially comprise of pictures, inscriptions, sound, recordings, numerical information focuses, etc., for tackling different Fake Insights challenges such as Image or video relegation Object location Face apperception Emotion relegation Verbalization analytics Sentiment analysis Stock showcase prospect, etc.

The first and the most important task was to arrange dataset according to our requirements. We used publicly available dataset.

We got good resolution Spinal X-ray images with their respective .mat file in which corner point of all 17 vertebrae were present.

Figure 8 Dataset Images with .mat files

There were some issues with some of the points where corner points were wrongly marked, we refined this.

We refined this by making a software where wrong point was removed,

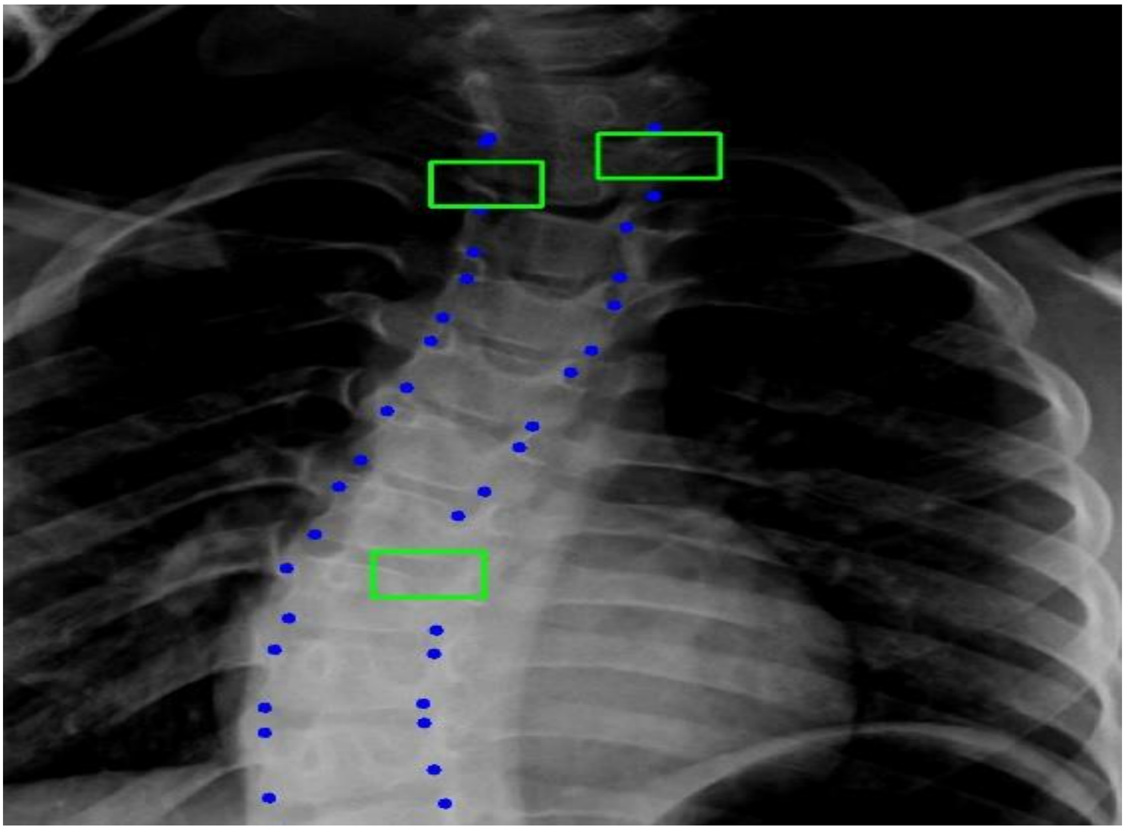

Figure 9 miss labelled points

and user will be asked manually to mark the approx. location of vertebrae in this region and this increased its accuracy significantly.

These approximate locations will then be stored in .txt file and then we update the .mat file of that particular image and then in this way we got our dataset in refined stage.This is one of the most important step in the machine learning because the accuracy of our Model output is greatly dependent on the accuracy of our input data set

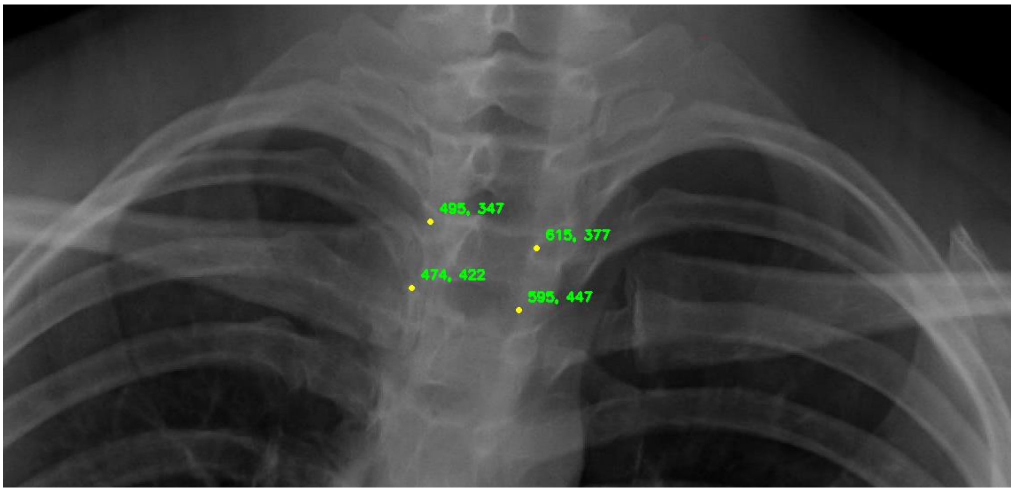

Figure 10 correctly labelled points

4.2 Pre processing

The major issues with all image processing software is the quality of software images, it is not possible to have the same quality and resolution of images according to which or Artificial intelligence model is trained pre processing steps are required to enhance the quality of image according to our software demand and make it ready to be able to act as an input to our software.

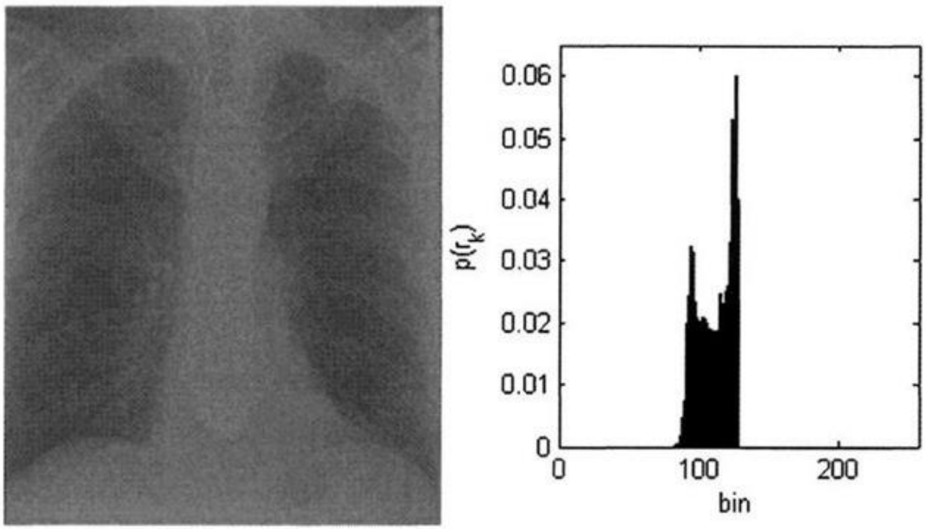

Figure 11 Pre-processing Steps 1

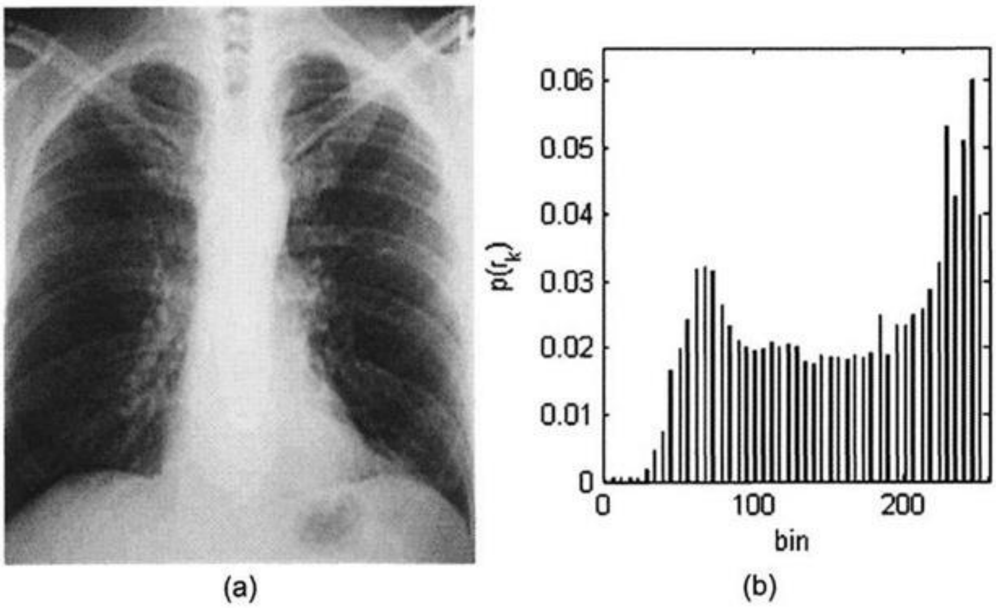

Figure 12 Pre-processing Steps 2

The main pre-processing steps in our software are:

1. Resizing the image according to our software input resolution on which our both models are trained.

2. Contrast enhancement is applied to all the input X-Ray image to make it easy for our Model to correctly localise it and then segmentate the vertebrae easily.

Last if model is unable to segment vertebrae correctly then apply contrast stretching again and again until we get vertebrae detected but if it is not, they display the appropriate error message on screen.

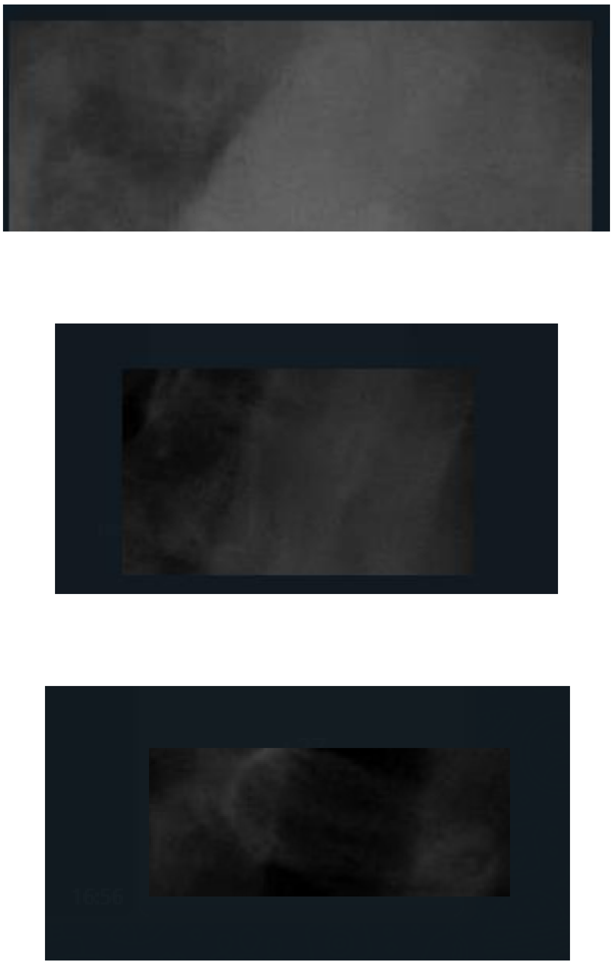

Figure 12 contract stretching image

4.3 Labelling

The dataset designating is the machine learning handle to agonize the crude information that moreover sanctions denominating the enlightening information, as well as paramount information to supply setting to it, and machine learning can utilize that information to memorize from it.

The denominating of information is the fundamental handle since it can integrate setting to information some time recently utilizing that within the preparing demonstrate, so that the information denominating makes a difference us to cull a redress approach when we require to move forward the multifariousness figure and the quality calculate, for case, on the off chance that we have any photo at that point denominating works to demonstrate whether the photo has creature or car which word may emerge in recording of the sound this moreover transpire in case we have an x-ray report in which it around x-ray report of having a tumour, so the dataset denominating is exceptionally critical when we have a assortment of utilize cases having the computerized vision, preparing of the prevalent dialect, and acknowledgment of the discourse.

Then comes the next step with the dataset that is labelling the vertebrae for training yolo v5

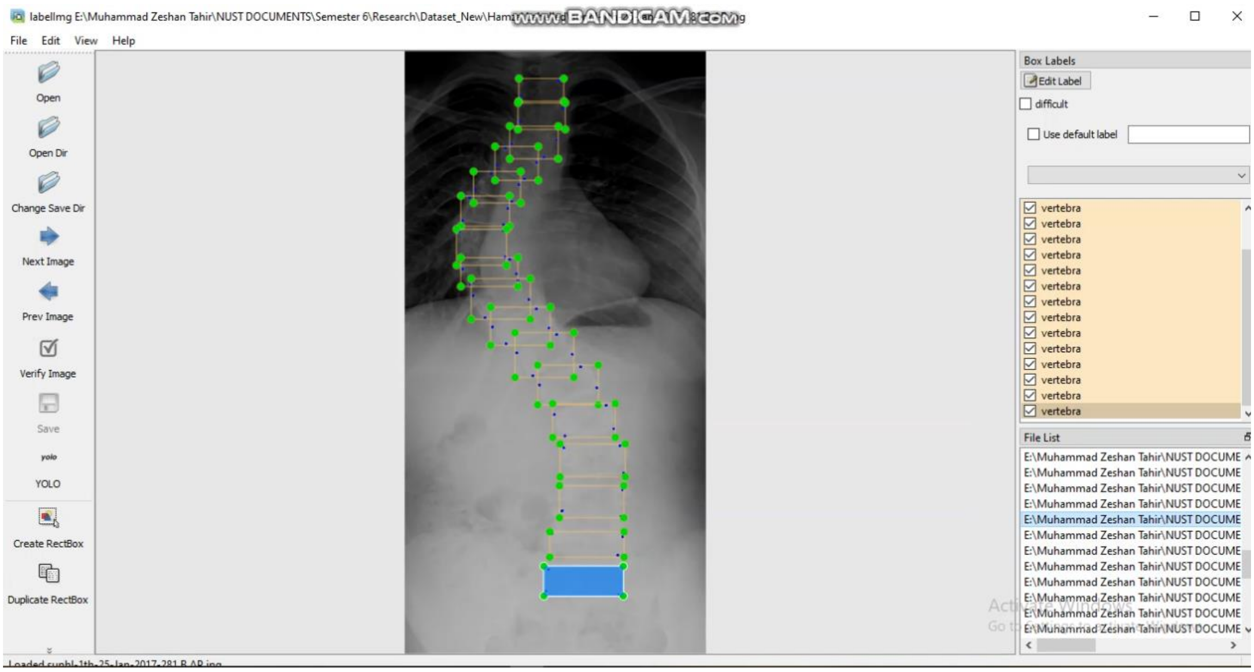

Figure 13 Labelling on YOLO v5

For labelling we used labelimg.py in this we label the rectangular region of all 17 vertebraes manually and it generated its corresponding .txt file according to our labeled rectangle.

LabelImg is a graphical image annotation implement.

It is inscribed in Python and uses Qt for its graphical interface.

Annotations are preserved as XML files in PASCAL VOC format, the format utilized by ImageNet. Besides, it additionally fortifies YOLO and CreateML formats.

```
15 0.560059 0.049316 0.299805 0.041016
15 0.538574 0.068848 0.293945 0.025391
15 0.492676 0.105469 0.293945 0.029297
15 0.424316 0.146240 0.284180 0.039551
15 0.349121 0.185547 0.266602 0.035156
15 0.280273 0.231201 0.257812 0.047363
15 0.246094 0.299072 0.212891 0.064941
15 0.271484 0.351318 0.257812 0.073730
15 0.332031 0.401611 0.271484 0.085449
15 0.429199 0.448242 0.290039 0.090820
15 0.544434 0.498779 0.319336 0.097168
15 0.656738 0.553467 0.338867 0.090332
15 0.722168 0.615479 0.317383 0.066895
15 0.719727 0.690674 0.347656 0.086426
15 0.647949 0.757812 0.366211 0.108398
15 0.512695 0.828857 0.382812 0.111816
15 0.396484 0.895508 0.386719 0.105469
```

Figure 13 vertices of vertebrae

To increase its accuracy, we also automated its labeling using the coordinates present in the mat file and this highly increased its efficiency.

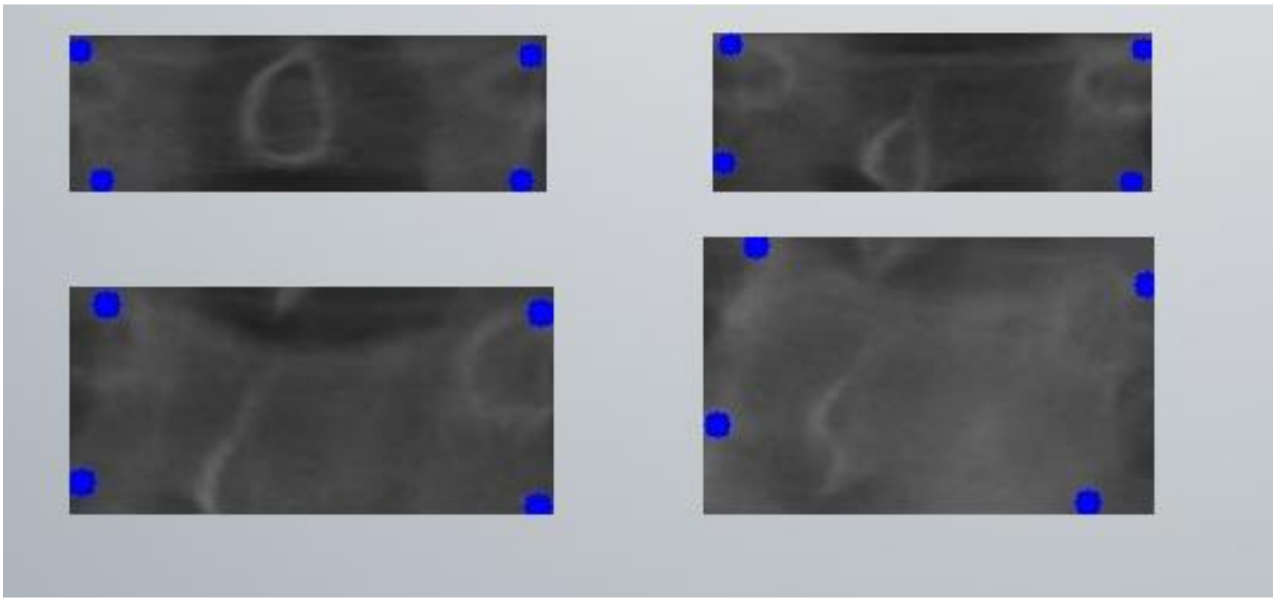

Figure 14 labelling of each vertebrae 1

And the end by combining the rectangle of vertebrae we got a binary image of complete spine.

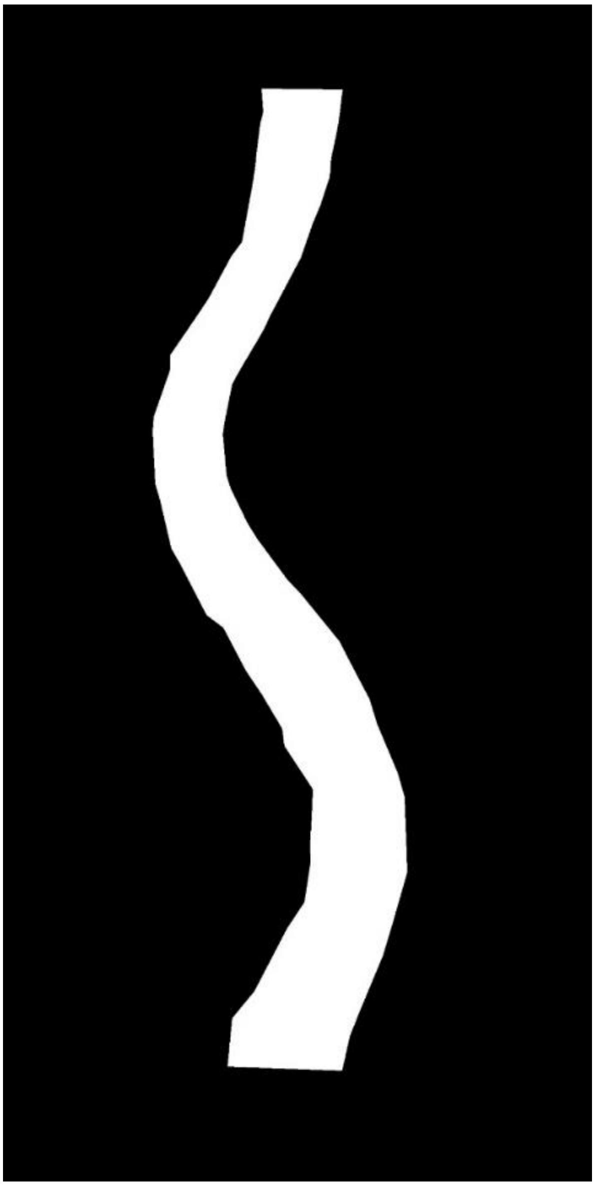

Figure 15 Binary Image of spine detected

As a result we got 98% accuracy in localization.

4.4 Localization

Yolo v5 Training:

The denominating of information is the fundamental handle since it can integrate setting to information some time recently utilizing that within the preparing demonstrate, so that the information denominating makes a difference us to cull a redress approach when we require to move forward the multifariousness figure and the quality calculate, for case, on the off chance that we have any photo at that point denominating works to demonstrate whether the photo has creature or car which word may emerge in recording of the sound this moreover transpire in case we have an x-ray report in which it around x-ray report of having a tumor, so the dataset denominating is exceptionally critical when we have a assortment of utilize cases having the computerized vision, preparing of the prevalent dialect, and acknowledgment of the discourse.

Then comes the next step with the dataset that is labelling the vertebrae for training yolo v5.

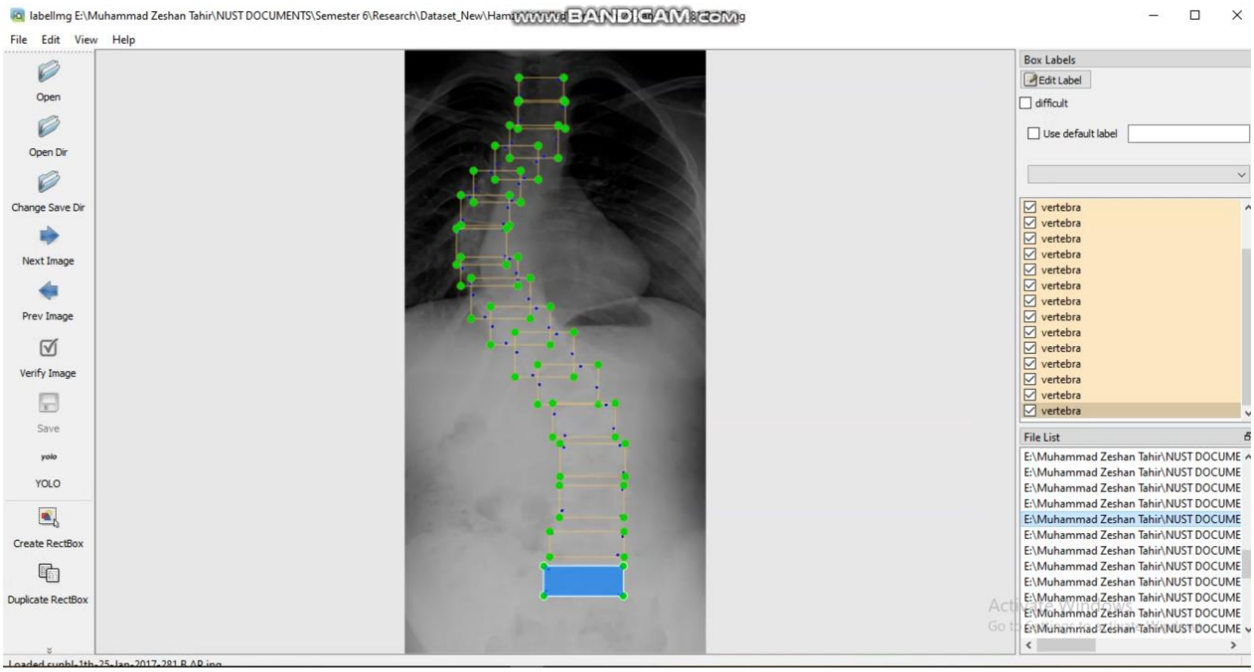

Figure 16 Labelling on YOLO v5 1

4.5 Results

This is the most important and 1st of the step to correctly identify the vertebrae of the spine in this our main task is to identify the local area in which we are sure that 1 vertebra is present we can call this our ROI and this is done by Yolo v5 which we trained and it correctly localizes all 17 vertebrae.

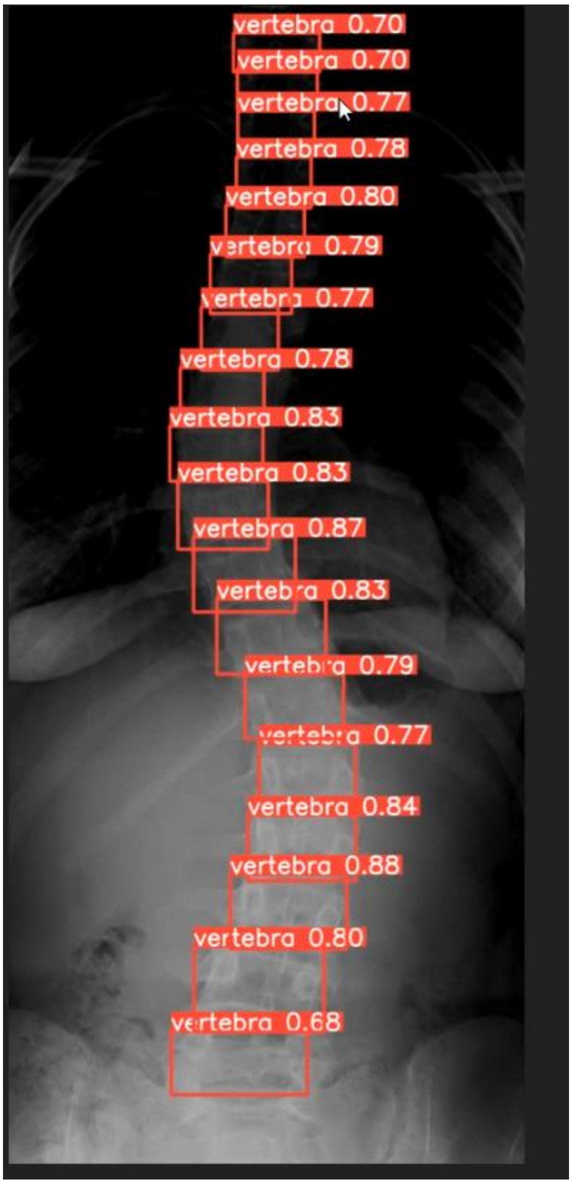

Figure 17 Localization of Vertebrae

As seen in this picture our YOLO v5 model predicted the 17 vebraes an the numerical values are the probability of each vertebrae to be present inside the spine

CHAPTER 5: METHODOLOGY

5.1 Segmentation

Segmentation of the vertebrae refers to the embryonic developmental process that result in the formation of the spine with a series of divided, similar anatomical units that are the vertebrae. There are total 17 vertebrae in a human spine.

The very next challenge after locating the vertebrae is to segment them out so that we can detect the exact 4 corner points of each vertebra that would help to calculate the Cobb angle of the spine.

For this purpose, we crop and rescale each vertebra and found the corner points of each vertebra.

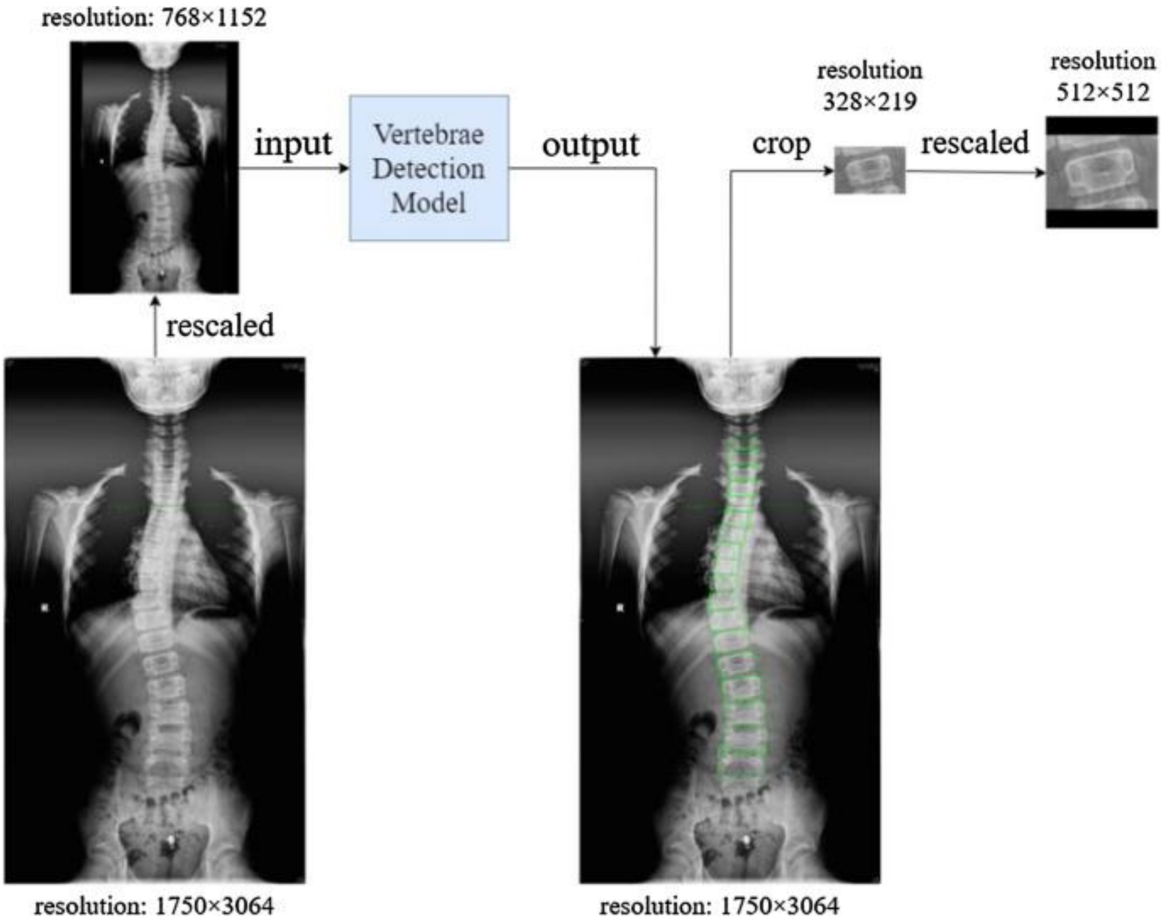

Figure 18 Cropped and resized vertebrae 1

5.2 UNET Training Model

Encoder-decoder architecture is synonymous with the U-net architecture. It is a deep-learning framework based on FCNs that is divided into two parts:

- A compact feature map captures context via a contracting path like an encoder.

▪ A symmetric expanding path that provides exact localization, akin to a decoder. This step is intended to ensure that boundary information (spatial information) is preserved despite the encoder stages down sampling and max pooling.

For the segmentation, we used the UNET Training Model. For that purpose, we have the dataset of 900 Images, few of them were divided to train and validation images along with their masks as shown in figure below.

Name ↑	Owner	Last modified
train_images	me	May 11, 2022
train_masks	me	May 11, 2022
val_images	me	May 11, 2022
val_masks	me	May 11, 2022

Figure 19 Dataset for Unet

Figure 20 Image of vertebra 1

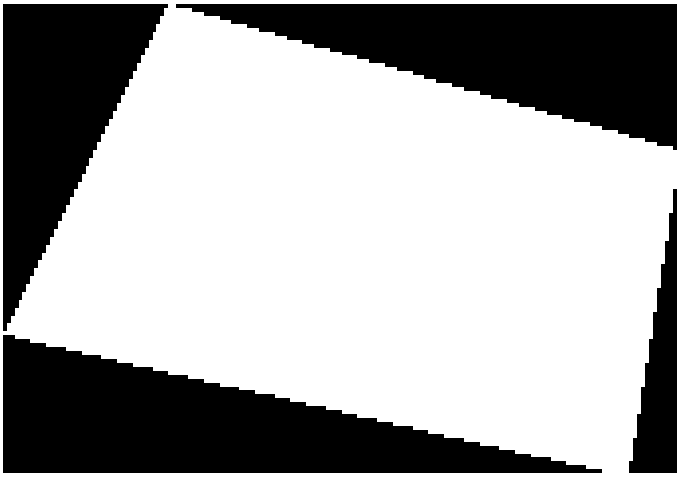

Figure 21 Masked Image

The encoder part of the proposed U-Net is on the left, and the decoder part is on the right. The encoder uses convolution and down sampling to extract information from the input image into feature maps. Using up sampling and concatenation of corresponding feature maps from the encoder side, the decoder reconstructs the prediction map from the encoded feature maps.

The figure below is the output of the U-Net Model, there is segmentation ground truth image of corresponding vertebra image.

The segmentation performances of U-Net were evaluated using 5-fold cross-validation. The training photos were increased to 1000 images in each fold, with 10% of them serving as validation images.

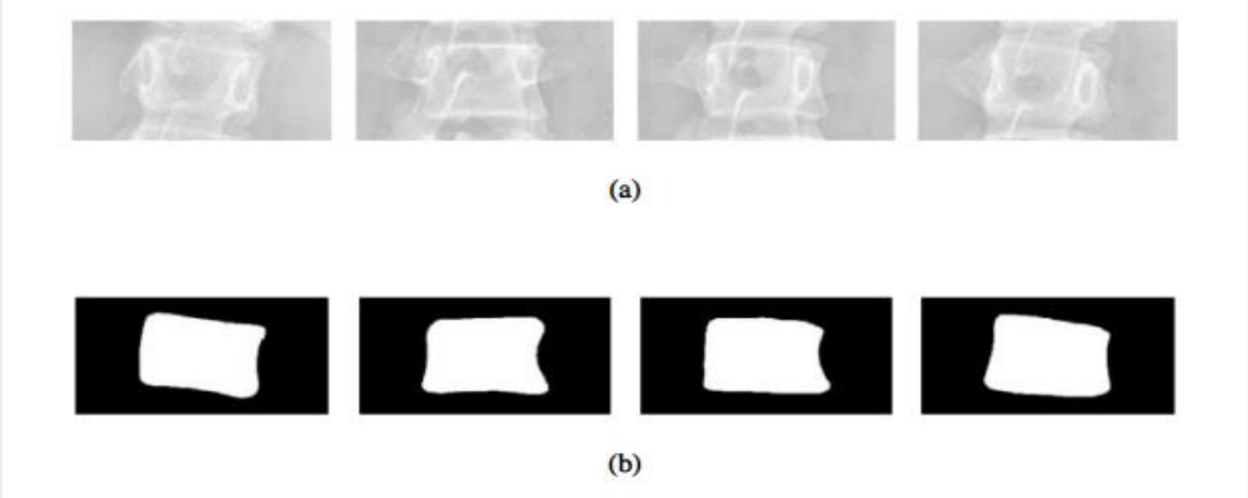

Figure 22 Vertebrae images (a) ROI of vertebrae (b) their corresponding annotated segmentation ground truth

5.3 Corner Point Detection

The four corners in each vertebral area were then located using keypoint detection technology. Another CenterNet-based model, CenterNet2, was presented for vertebral corner identification. It was divided into two parts: the backbone and the output heads .

The relative positions of the corners with relation to the centre were called corner locations. The discretization error of the corners was the corner offset.

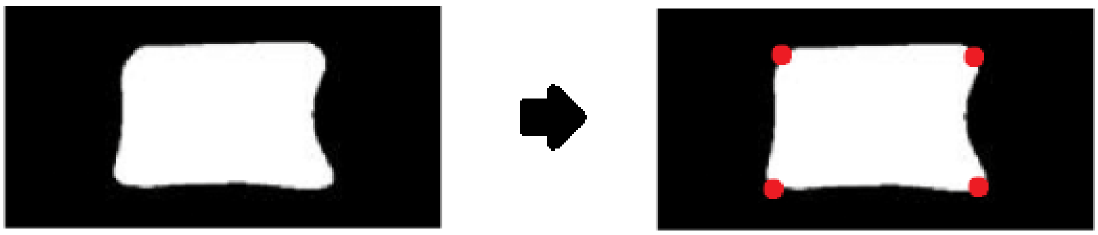

Figure 23 Corner point detection

After applying the algorithm, we got the corner points of all the 17 vertbrae of the spine we shown in figure below:

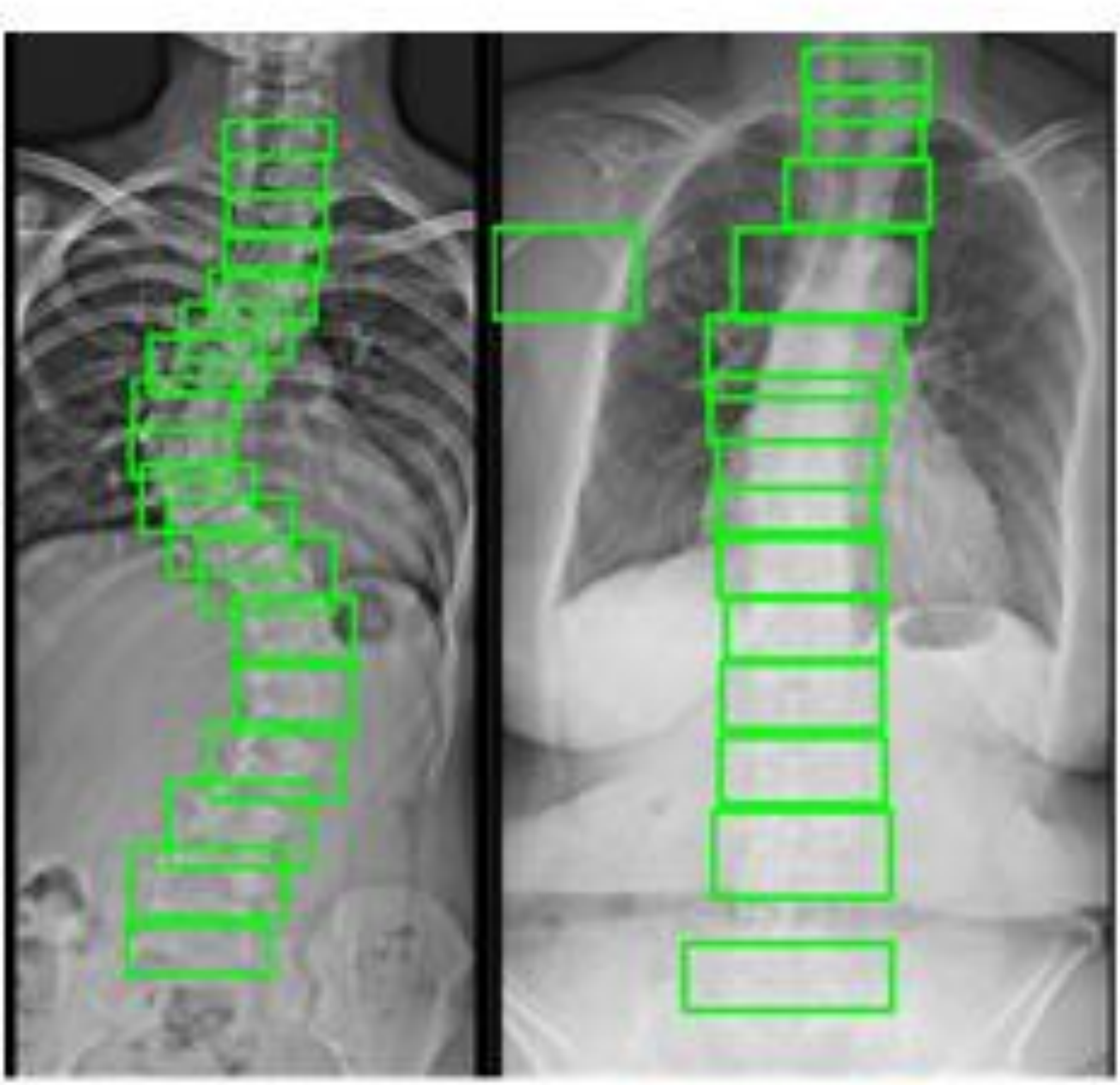

Figure 14 labelled X-ray

Figure 24 corner points detected

5.4 Measurement of Cobb Angle

The angle formed by the upper endplate of the upper end vertebra and the lower endplate of the lower end vertebra is known as the Cobb angle.

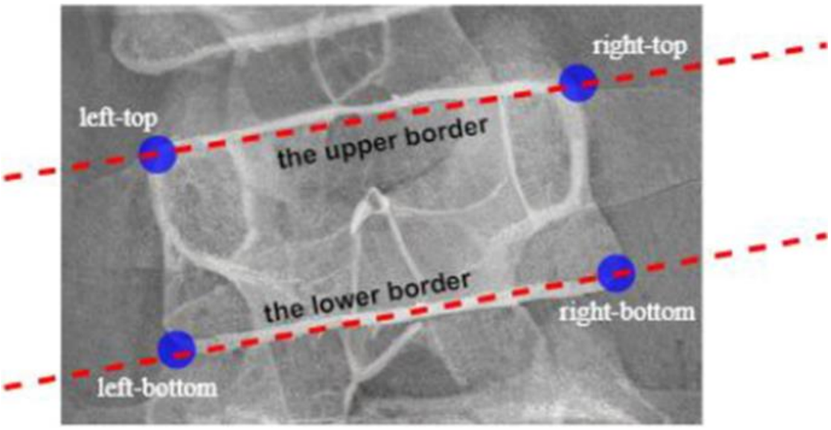

Figure 25 Upper and lower border of vertebrae

For each vertebra, the upper endplate was defined as the line joining the left-top corner and the right-top corner, and the lower endplate was defined as the line connecting the left-bottom corner and the right-bottom corner as shown in the above figure.

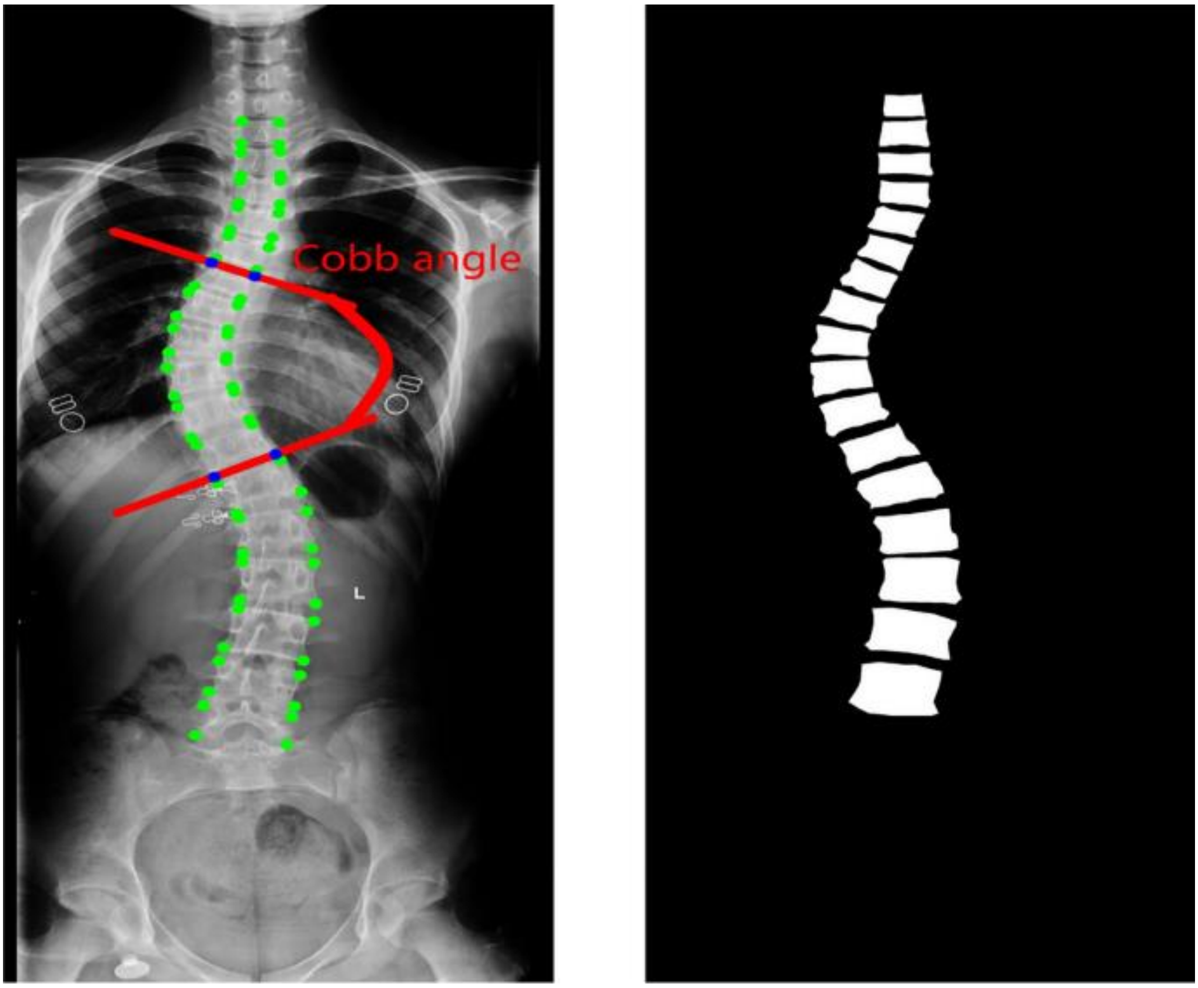

Figure 26 Cobb Angle Calculation

Each angle formed by distinct vertebrae is calculated recursively by altering the lower and higher end vertebrae from top to bottom to achieve the Cobb angle. Cobb angles in the upper and lower curves will be measured in a similar manner after the Cobb angle of the main curve has been determined. A spinal X-ray is used to demonstrate the detection result.

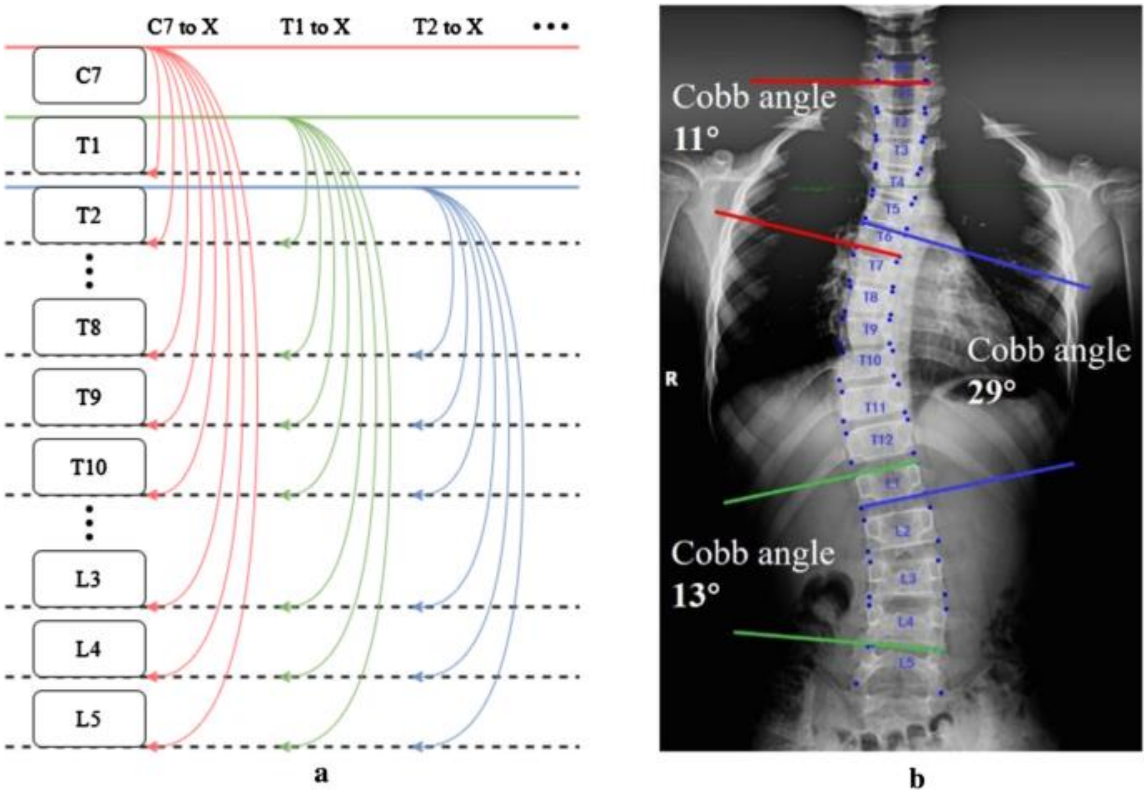

Figure 27 Cobb Angle Calculation

Finally, descriptive statistics such as means and standard deviations for all patient characteristics were determined for each group (expert annotated and deep learning located).

The intra-class correlation coefficient (ICC) was used to assess the reliability of the Cobb angles calculated by the proposed deep learning method, while the Pearson correlation coefficient, mean absolute error, and Spearman rank-order correlation were used to investigate the relationships between deep learning results and expert annotation, as needed.

CHAPTER 6: Software Tools

6.1 PyCharm

It is a Python Integrated Development Environment (IDE) that includes a variety of key tools for Python developers that are tightly integrated to create a pleasant environment for effective Python, web, and data science development. We used PyCharm to run the Python code of our project. [14]

6.2 Google Colab

Figure 28 google Colab

Colab is a Google Research product. Colab is a web-based Python editor that allows anyone to write and run arbitrary Python code. It's notably useful for machine learning, data analysis, and education. Colab, in more technical terms, is a hosted Jupyter notebook service that requires no installation and provides free access to computer resources, including GPUs. [15]

6.3 LabMe.py

By classifying retinal illnesses, a crowdsourcing platform for labelling fundus images aids in the improvement of an AI system. We used the LabMe software to label our vertebrae manually. [16]

Figure 28 LabelMe

CHAPTER 7: LITERATURE REVIEW

AI is growing vastly in **medical imaging** and automated systems have been developed by many researchers to diagnose different diseases and help the doctor to choose less invasive surgical procedures. Bio-medical imaging in combination with AI are rapidly growing and producing digital diagnosis systems to facilitate the medical experts in clinical examination without any physical procedure.

Adequate work is done to diagnose postural issues and spinal deformities

Researchers investigated different types of spinal deformities and tried to diagnose the diseases through **segmentation** and **regression methods** and to find **Cobb Angles** to identify the disease

Various approaches can be used to measure **Cobb Angles** which help in identification of curvature deformity.

7.1 Classic Literature

Firstly, here is a glimpse of classical method for spine deformity evaluation. In 19th century spinal deformities were measured manually with help of inclinometer and Cobb angle calculations.

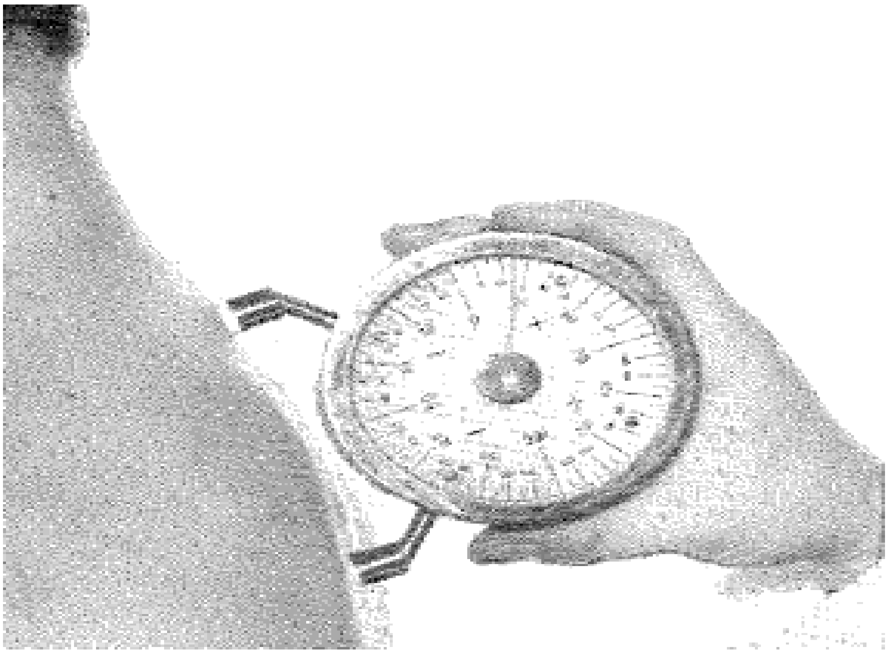

Figure 29 Loebl 1967 Inclinometer for measuring spinal curvature [17]

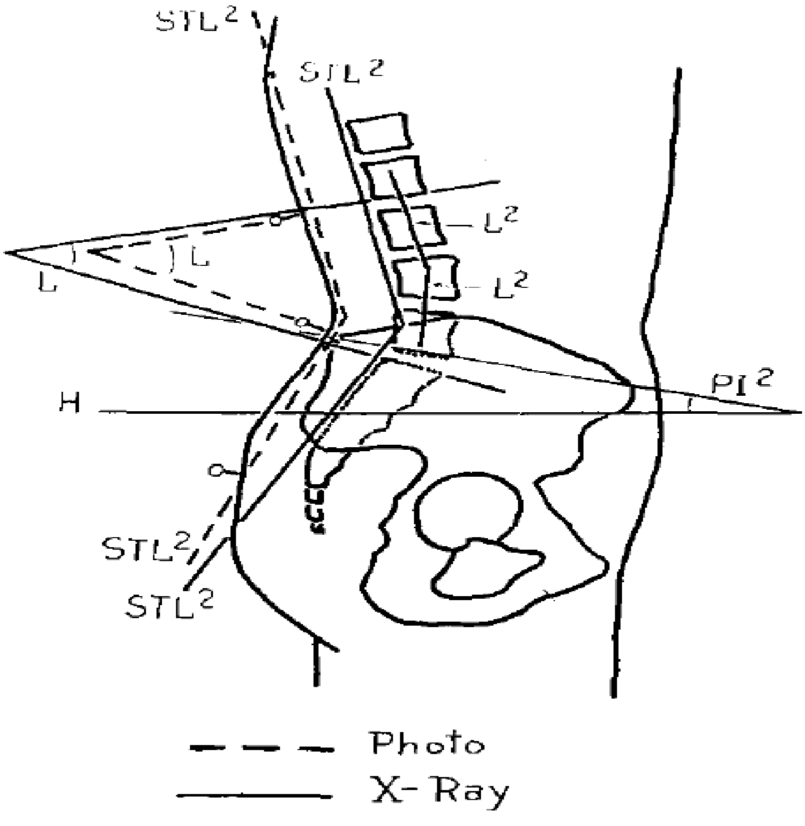

Figure 30 M. ***Marilyn Flint 1963 Cobb Calculation Technique*** [18]

This method assumes that the curvature of spinal segment can be defined by the angle formed by two tangent points.

Our literature study is divided like our proposed framework. In first view the latest literature is shown of past 5 years to give a summary regarding areas and techniques used for localization and segmentation.

The research in this domain revolves around UNet frameworks. All these researchers focus to localisation the spine and to segmentation of the vertebrae.

7.2 Localization and Segmentation Literature

Study	Technique	Detection	Dataset	Dice Results
Shi et al. 2018	Coronal spinal centreline, intensity curve and 3D U-Net	Spine Localization	61 CT	0.80
Rehman et al. 2019	FU-Net framework and Region-based deep U-Net	Osteoporotic	CSI	0.92
Liebl et al. 2020	Btrfly Net and U-Net	Segmentation	VerSe20	0.91

Table 2 – Localization and Segmentation Literature

7.3 Shape Analysis and Cobb Estimation Literature

Study	Technique	Diseases	Dataset	Results
Safari et al. 2019	Manual Landmarking and Curve fitting and Cobb	Scoliosis	14 X-Rays	Correlation Coefficient 0.81
Bo Chen et al. 2019	Adaptive Error Correction Net (AEC-Net)	Scoliosis	581 X-Ray	MAE 4.90
Kim et al. 2020	Centroid-net M-Net	Scoliosis	481 X-Ray	SMAPE 7.84%
Alharbi et al 2020	CLAHE, ResNet50 and LineAngles bw center points	Scoliosis	243 X-Ray	--
Liu et al. 2020	Multi-scale Deeplab V3+ SDP	AIS	157 X-Ray	Dice 0.9379 ± 0.0286
Zhang et al. 2021	FCN, Spinal Landmarks and Segmentation Network (SLSN)	Scoliosis	AASCE 19	SMAPE 25.99%
Cui et al. 2021	U-net network and convex hull algorithm	Scoliosis	AASCE 19	SMAPE 21.675%
Wang et al. 2021	PSPNet , ResNet Regression and DenseNet	Scoliosis	AASCE 19	SMAPE 21.71%

Table 3 - Shape Analysis and Cobb Estimation Literature

Research Gaps

- Most of the work in the literature is carried out on segmentation of each vertebra.
- Conventional methods failed to extract vertebra in the presence of noise and low contrast.
- Deep learning-based methods mostly tried to segment each vertebra which tend to fail in presence of deformed regions.
- In addition to this, automated spinal deformity classification methodologies for all categories are absent in existing work.
- The shape analysis-based scheme, to classify the shape-based difference in scoliosis to assess normal, C and S shape of curvature is one of major gap that needs attention as both curvature shapes define treatment plan of the massage pattern, brace styling and exercises.
- To the best of our knowledge, there is no single framework which is proposed to handle different imaging modalities and clinical parameters related to spinal deformities.

CONTRIBUTIONS

A novel single framework is proposed to handle different imaging modalities and clinical parameters related to spinal deformities

The object detection framework is utilized for vertebrae localization from different imaging modalities and its centroids are used to classify the Shapes.

A comparative analysis of different classifiers and deep segmentation models has been performed.

Clinical approaches are studied and made part of proposed system for reliable Cobb angle estimation.

Chapter 8: Conclusion

A single framework is presented for diagnosis of all three spine deformities. All imaging modalities are addressed without any restriction of regional segregation in spine column. Annotations and Labelling of Datasets is produced. A new set of features has been proposed for shape analysis.

As everything is now getting digital and Automated with the advancement of technology. Similarly, our product is advanced solution of manual detection of Scoliosis. It is based on a Smart Web App where the user would need to just upload the Spinal x-ray image and get the output report that is now more efficient, faster, accurate and easy way to find Cobb Angle and generate the automated report. Many patient's reports would automatically be generated in faster way without the need of a doctor with minimal human effort.

If hospitals would integrate this app, there would be more chance that they could serve more patients than normal with better results.

Chapter 9: Future Work

This shows that along with human resources we have to work on automated machines which can doesn't require much experience to operate this machines if work on these models can perform automated surgery with very low Dr involvement and will automatically adjust spine to the best position with minimum time, effort and reduced error risk.

In case of accident of a person if automated system is a available then doctor just don't have to wait for senior doctor and Radiologist to perform surgery because in the accidents timely surgery is the major thing to save life of patients because if surgery is not performed well within time then it can lead to

- Permanent Disability
- Physical Handicap
- Neuro Disorder
- Limbs Disorder
- Death of Patient

Almost all Spine diseases like

- Arthritis
- Degenerative disc disease
- Herniated disc
- Spinal stenosis
- Spondylosis

And mainly spine curvature disorders like

- **Lordosis**. Also called swayback, the spine of a person with lordosis curves significantly inward at the lower back.
- **Kyphosis.** Kyphosis is characterized by an abnormally rounded upper back (more than 50 degrees of curvature).
- **Scoliosis.** A person with scoliosis has a sideways curve to their spine. The curve is often S-shaped or C-shaped.

can be predicted accurately with these models if the appropriate dataset is available and appropriate labelling and training is done.

References

[1] James McIntosh, What is causing this pain in my back? on February 23, 2017,https://www.medicalnewstoday.com/articles/172943

[2] Back Pain Facts and Statistics, https://handsdownbetter.org/health-and-wellness/back-pain-facts-and-statistics/

[3] Spinal cord injury, https://www.who.int/news-room/fact-sheets/detail/spinal-cord-injury

[4] vertebral column, vertebral column | Anatomy & Function | Britannica

[5]Picture available online: https://cdn.britannica.com/57/54757-050-99173B1B/Human-vertebral-column.jpg

[6] Scoliosis, available online: https://www.aans.org/Patients/Neurosurgical-Conditions-and-Treatments/Scoliosis#:~:text=Scoliosis%20is%20an%20abnormal%20lateral,%2Dcalled%20%E2%80%9Csagittal%E2%80%9D%20plane.

[7] Scoliosis, https://www.drugs.com/health-guide/scoliosis.html

[8] J. Cobb, "Outline for the study of scoliosis," Instructional Course Lectures, vol. 5, pp. 261–275, 1948

[9] Horng, Ming-Huwi, et al. "Cobb angle measurement of spine from X-ray images using convolutional neural network." *Computational and mathematical methods in medicine* 2019 (2019).

[10][11][12] Scoliosis Treatment in Adults – Is It Possible to Avoid Scoliosis Surgery?

https://regenexx.com/blog/scoliosis-treatment-in-adults/#gref

[13] Accurate Automated Spinal Curvature Estimation MICCAI 2019 Challenge Dataset," AASCE 2019. [Online]. Available: https://aasce19.github.io/#challenge-dataset

[14] PyCharm https://www.jetbrains.com/pycharm/

[15] Google Colab https://research.google.com/colaboratory/

[16] Labelme https://github.com/wkentaro/labelme

[17] M. M. Flint, "Lumbar posture: a study of roentgenographic measurement and the influence of flexibility and strength," *Research Quarterly. American Association for Health, Physical Education and Recreation*, vol. 34, no. 1, pp. 15–20, 1963.

[18] W. Y. Loebl, "Measurement of spinal posture and range of spinal movement," *Rheumatology*, vol. 9, no. 3, pp. 103–110, 1967.