Estimation of Spinal Curvature Using Machine Learning

S.G. Shivabhinav, K.S. Puvivarun and J. Briskilal

Abstract--- *One of the common types of scoliosis is Adolescent Idiopathic Scoliosis which affects children between ages 10 to 18.Generally, AIS curves progresses rapidly during the teenage years of patients. Growth progression of many curves grow significantly during skeletal maturity, but curves with more than 60o, progresses even during adult-hood. Since this problem it starts at an early age is difficult to diagnose it since the angle of curvature is small and is generally recognised at older ages say around 45 years. Symptoms of this is generally not observed at the early age and generally is visible during late teens. It causes lower back pain, height asymmetry, lean torso, and may cause problems to nerves. To solve this problem generally we measure Cobb angle manually which is more time-consuming and unreliable. It is very challenging to achieve a highly accurate estimation of Cobb angles as it is difficult to utilize the information of x-rays efficiently. This has sparked interest in developing methods for accurate automated spinal curvature estimation and error correction in spinal anterior-posterior x-ray images. This is done using convolutional neural networks (CNN) and other artificial neural networks (ANN).In order to estimate accurate spinal curvature and Cobb angle we use machine learning.*

Keywords--- *AIS-Adolescent Idiopathic Scoliosis, Cobb Angle, CNN-Convolutional Neural Networks, ANN-Artificial Neural Networks.*

I. INTRODUCTION

AIS is the most common type of scoliosis which affects children between ages 10 to 18. Generally, AIS curves progress during the growth of the patient. Cause of AIS is hormonal imbalance, asymmetric growth and muscle imbalance. [1]

- ***Symptoms***

AIS patients have no pain or neurologic abnormalities. Even when viewed from the side, they have a normal appearance [2]. However, several visible symptoms which are associated with AIS:

Rib "hump"—A prominent hump on the back. One of the visible signs of scoliosis is rib hump. Shoulder height asymmetry—When one shoulder appears to be higher than the other. Torso "lean"— A shift of the body which occurs especially when there is only a single curve in the thoracic (chest- part) or the lumbar (lower back) of the spine with no second curve to support the patient [3].This can appear as waistline asymmetry where one hip appears to be higher than the other and can result in one leg appearing longer than the other [1].

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- ***Causes***

Most of the doctors don't know the cause for common type of scoliosis — it appears to involve hereditary factors, because the disease runs in the families [4]. Less common types of scoliosis can be caused by: Neuromuscular conditions, such as cerebral palsy or muscular dystrophy. Birth defects affecting the development of the bones present in the spine. Spinal injuries and infections[5].

- ***Diagnosis***

During the physical examination, doctor makes the child stand and afterwards asks the child to bend forward from the waist, with his arms hanging loosely, to see whether one side of the rib cage is more prominent than the other[1]. Doctor will perform neurological exams for: Muscle Weakness Numbness Abnormal reflexes. Imaging tests and Plain X-rays can confirm the diagnosis of scoliosis which would reveal the severity of the spinal curvature. If there is a tumor which is causing the scoliosis, doctor may recommend MRI[2].

- ***Treatment Observation***

Observation is used for patients whose curves are less than 25 to 30º and are still growing —or for curves less than 45ºin patients who have completed their growth[9].

Bracing

The job of a scoliosis brace is to halt or slow progression of the curve – with an ultimate goal of avoiding a spinal fusion surgery (and the recovery and limitations that go with it) [10].

Surgery

Surgical treatment is often recommended for patients whose curves are greater than 45 while still growing, or are continuing to progress greater than 45 when growth stopped[7].The surgery can be performed with either a posterior approach or anterior approach[8]:

- *Posterior approach*: A straight incision is made along the midline of the back. This method is widely used in the treatment of AIS and is very effective.
- *Anterior approach*: A straight incision is made through the front of spine. This method is used when there is a single thoracic curve or a single lumbar curve is being treated.

II. PREVIOUS SYSTEM

The present system is that the specialist doctors are manually diagnosing the angle of curvature of the spine using the x-ray images and scans[2]. The disadvantage of the system is that it takes a lot of time to predict the angle and hence the treatment process gets delayed. The other disadvantage is that doctors can only predict the angles at the late stages of the disease which is at generally between 40-45 years thereby resulting in late treatment in some cases [12].

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III. PROPOSED METHOD

The proposed method is that using machine learning algorithms, we can diagnose the cobb angle in the spinal curvature by processing the images by keeping only the edge and boundary detection, then we fix the coordinates of the edges and estimate the angle using normal drawn to the spinal curvature at the point of start, end and in the middle[13]. This is more easy and efficient and can detect the angle earlier than manual detection and can be detected around 10-18 years [16].

At the beginning the dataset is loaded and then pre-processed[20]. The images of the spine are converted to black and white or x-ray images.

Image Pre-processing is used to clear all the noises from the input image[18]. Edge detection and boundary detection using canny function. Canny Edge detection is used to detect the edges in an image. It accepts even a grey scale image [13].

Then after the edge detection we use vectors and normal to find the cobb angle subtended by the spine after removing the noises in the image[17]. The cobb angle is the angle which is subtended between the normals drawn at the point of curvature. We find the angle at three points of curvature per image, one at the top, one in the middle, and one at bottom. The point in the middle is the more important one[14].

We then use resnet-50 architecture in convolutional neural network to classify the cobb angles[20]. Angles between 0 – 20 is given least priority, 20- 40 is given higher priority and the above 40 is the highest priority[6].

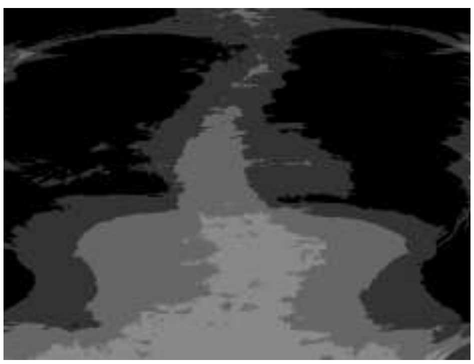

Fig. 1: Image before pre-processing

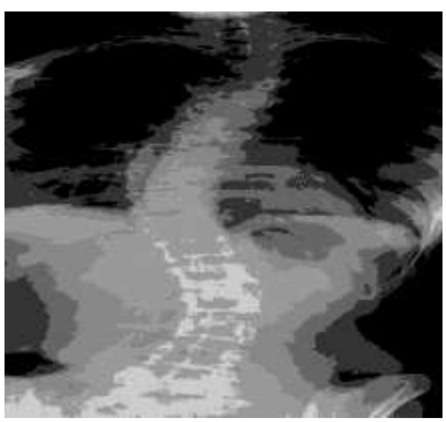

Fig. 2: Image after pre-processing

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IV. INFERENCE

We infer that Cobb angle can be accurately estimated by means of machine learning algorithms and neural network architectures. We also infer that by this means we can detect the problem at an early stage and provide adequate treatment.

V. IMPLEMENTATION

```
for k=1:N
    %get images
    l = [folder_im fileNames_im{k}];
    im = imread(l);
    [H,W] = size(im);

    %get labels
    l_n = [folder_l fileNames_l{k}];
    p = load(l_n);
    coord = p.p2;

%       p2 = [landmarks(k,1:68) ; landmarks(k,69:136)]';
    if isempty(strfind(lower(l_n),'lateral'))
        p2 = [coord(1:ap_num) ; coord(ap_num+1:ap_num*2)]';
        vnum = ap_num / 4;
        landmarks_ap = [landmarks_ap ; coord(1:ap_num)/W, coord(ap_num+1:ap_num*2)/H]; %scale landmark coordinates
    else
        p2 = [coord(1:lat_num) ; coord(lat_num+1:lat_num*2)]';
        vnum = lat_num / 4;
        landmarks_lat = [landmarks_lat ; coord(1:lat_num)/W, coord(lat_num+1:lat_num*2)/H]; %scale landmark coordinates
    end
    cob_angles = zeros(1,3);

    figure,imshow(im)
    title('GroundTruth');
    hold on

    mid_p_v = zeros(size(p2,1)/2,2);
    for n=1:size(p2,1)/2
        mid_p_v(n,:) = (p2(n*2,:) + p2((n-1)*2+1,:))/2;
    end
```

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```
      %calculate the middle vectors & plot the labeling lines
      mid_p = zeros(size(p2,1)/2,2);
      for n=1:size(p2,1)/4
          mid_p((n-1)*2+1,:) = (p2(n*4-1,:) + p2((n-1)*4+1,:))/2;
          mid_p(n*2,:) = (p2(n*4,:) + p2((n-1)*4+2,:))/2;
      end

      %pause(1)
      %plot the midpoints
      plot(mid_p(:,1),mid_p(:,2),'y.','MarkerSize',20);
      %pause(1)

    vec_m = zeros(size(mid_p,1)/2,2);
      for n=1:size(mid_p,1)/2

    vec_m(n,:) = mid_p(n*2,:) - mid_p((n-1)*2+1,:);
          %plot the midlines
          plot([mid_p(n*2,1),mid_p((n-1)*2+1,1)],...
              [mid_p(n*2,2),mid_p((n-1)*2+1,2)],'Color','r','LineWidth',2);
      end

  mod_v = power(sum(vec_m .* vec_m, 2),0.5);
      dot_v = vec_m * vec_m';

  %calculate the Cobb angle

      angles = acos(roundn(dot_v./(mod_v * mod_v'),-8));
      [maxt, pos1] = max(angles);
      [pt, pos2] = max(maxt);
      pt = pt/pi*180;
      cob_angles(1) = pt;

      %plot the selected lines
      %pause(1)
      plot([mid_p(pos2*2,1),mid_p((pos2-1)*2+1,1)],...
          [mid_p(pos2*2,2),mid_p((pos2-1)*2+1,2)],'Color','g','LineWidth',2);
      plot([mid_p(pos1(pos2)*2,1),mid_p((pos1(pos2)-1)*2+1,1)],...
          [mid_p(pos1(pos2)*2,2),mid_p((pos1(pos2)-1)*2+1,2)],'Color','g','LineWidth',2);
```

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```
    if ~isS(mid_p_v) % 'S'

        mod_v1 = power(sum(vec_m(1,:) .* vec_m(1,:), 2),0.5);
        mod_vs1 = power(sum(vec_m(pos2,:) .* vec_m(pos2,:), 2),0.5);
        mod_v2 = power(sum(vec_m(vnum,:) .* vec_m(vnum,:), 2),0.5);
        mod_vs2 = power(sum(vec_m(pos1(pos2),:) .* vec_m(pos1(pos2),:), 2),0.5);

        dot_v1 = vec_m(1,:) * vec_m(pos2,:)';
        dot_v2 = vec_m(vnum,:) * vec_m(pos1(pos2),:)';

        mt = acos(roundn(dot_v1./(mod_v1 * mod_vs1'),-8));
        tl = acos(roundn(dot_v2./(mod_v2 * mod_vs2'),-8));

        mt = mt/pi*180;
        cob_angles(2) = mt;
        tl = tl/pi*180;
        cob_angles(3) = tl;

    else
    % max angle in the upper part
        if (mid_p_v(pos2*2,2) + mid_p_v(pos1(pos2)*2,2)) < size(im,1)

            %calculate the Cobb angle (upside)
            mod_v_p = power(sum(vec_m(pos2,:) .* vec_m(pos2,:), 2),0.5);
            mod_v1 = power(sum(vec_m(1:pos2,:) .*

vec_m(1:pos2,:), 2),0.5);
            dot_v1 = vec_m(pos2,:) * vec_m(1:pos2,:)';



            angles1 = acos(roundn(dot_v1./(mod_v_p * mod_v1'),-8));
            [CobbAn1, pos1_1] = max(angles1);
            mt = CobbAn1/pi*180;
            cob_angles(2) = mt;

            plot([mid_p(pos1_1*2,1),mid_p((pos1_1-1)*2+1,1)],...
                [mid_p(pos1_1*2,2),mid_p((pos1_1-1)*2+1,2)],'Color','g','LineWidth',2);

            %calculate the Cobb angle?downside?
```

```
            mod_v_p2 = power(sum(vec_m(pos1(pos2),:) .*

vec_m(pos1(pos2),:), 2),0.5);
            mod_v2 = power(sum(vec_m(pos1(pos2):vnum,:) .*
vec_m(pos1(pos2):vnum,:), 2),0.5);
            dot_v2 = vec_m(pos1(pos2),:) * vec_m(pos1(pos2):vnum,:)';

            angles2 = acos(roundn(dot_v2./(mod_v_p2 * mod_v2'),-8));
            [CobbAn2, pos1_2] = max(angles2);
            tl = CobbAn2/pi*180;
            cob_angles(3) = tl;

            pos1_2 = pos1_2 + pos1(pos2) - 1;
            plot([mid_p(pos1_2*2,1),mid_p((pos1_2-1)*2+1,1)],...
                [mid_p(pos1_2*2,2),mid_p((pos1_2-1)*2+1,2)],'Color','g','LineWidth',2);

        else
            %calculate the Cobb angle (upside)
            mod_v_p = power(sum(vec_m(pos2,:) .* vec_m(pos2,:), 2),0.5);
            mod_v1 = power(sum(vec_m(1:pos2,:) .* vec_m(1:pos2,:), 2),0.5);
            dot_v1 = vec_m(pos2,:) * vec_m(1:pos2,:)';

           angles1 = acos(roundn(dot_v1./(mod_v_p * mod_v1'),-8));
            [CobbAn1, pos1_1] = max(angles1);
            mt = CobbAn1/pi*180;
            cob_angles(2) = mt;

            plot([mid_p(pos1_1*2,1),mid_p((pos1_1-1)*2+1,1)],...
                [mid_p(pos1_1*2,2),mid_p((pos1_1-1)*2+1,2)],'Color','g','LineWidth',2);

            %calculate the Cobb angle (upper upside)
            mod_v_p2 = power(sum(vec_m(pos1_1,:) .* vec_m(pos1_1,:), 2),0.5);
            mod_v2 = power(sum(vec_m(1:pos1_1,:) .* vec_m(1:pos1_1,:), 2),0.5);
            dot_v2 = vec_m(pos1_1,:) * vec_m(1:pos1_1,:)';

angles2 = acos(roundn(dot_v2./(mod_v_p2 * mod_v2'),-8));
            [CobbAn2, pos1_2] = max(angles2);
            tl = CobbAn2/pi*180;
            cob_angles(3) = tl;
```

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```
%pos1_2 = pos1_2 + pos1(pos2) - 1;
            plot([mid_p(pos1_2*2,1),mid_p((pos1_2-1)*2+1,1)],...
                [mid_p(pos1_2*2,2),mid_p((pos1_2-1)*2+1,2)],'Color','g','LineWidth',2);
        end
    end
    %pop up a text window
%       pause(1)
    output = [ num2str(k) ': the Cobb Angles(PT, MT, TL/L) are '  num2str(pt) ', ' num2str(mt) ' and ' num2str(tl) ...
        ', and the two most tilted vertebrae are ' num2str(pos2) ' and ' num2str(pos1(pos2)) '.\n'];
    %h = msgbox(output);

     fprintf(output);
    %             fprintf('No. %d :The Cobb Angles(PT, MT, TL/L) are %3.1f, and the two most tilted vertebrae are %d and %d. ',...
    %                 k,CobbAn,pos2,pos1(pos2));

   %pause(2)
    close all

 if isempty(strfind(lower(fileNames{k}),'lateral'))
        CobbAn_ap = [CobbAn_ap ; cob_angles]; %cobb angles
    else
        CobbAn_lat = [CobbAn_lat ; cob_angles]; %cobb angles
    end
end

% write to csv file
csvwrite('angles_ap.csv',CobbAn_ap);
csvwrite('angles_lat.csv',CobbAn_lat);
csvwrite('landmarks_ap.csv',landmarks_ap);
csvwrite('landmarks_lat.csv',landmarks_lat);
fid = fopen('filenames_aplat.csv','wt');
if fid>0
    for k=1:N
        fprintf(fid,'%s\n',fileNames_im{k});
    end
        fclose(fid);
end
```

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VI. FUTURE WORK

If we include more layers in the neural network accuracy may increase. We can also use other neural network architectures to classify the cobb angle which may yield a better result.

VII. CONCLUSION

The count of Adolescent Idiopathic Scoliosis is increasing every year and early diagnosis is required to prevent this disease. Improper diagnosis of AIS can cause paralysis and eternal suffering. One of the ways to tackle this challenge is through the application of Machine Learning, Neural Network and Computer Vision techniques. In this paper, an analytical review of several research papers has been done to document the current progress in the Detection of Spinal curvature.

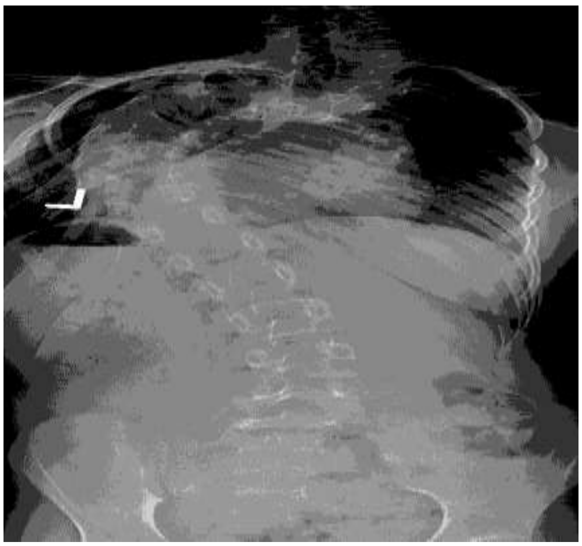

Fig. 3: Priority 1

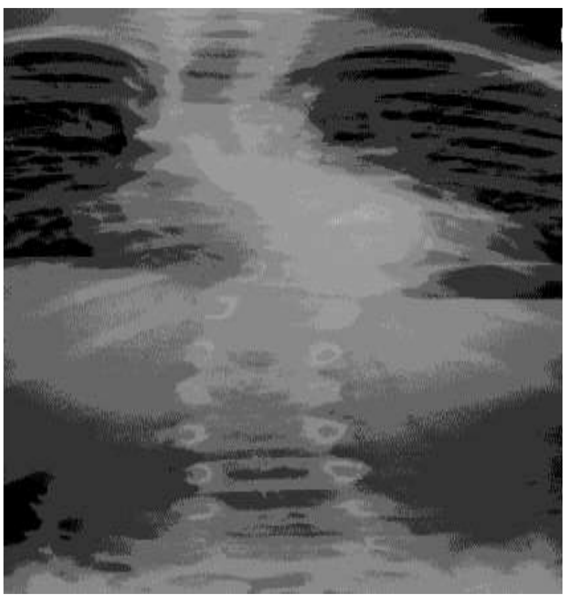

Fig. 4: Priority 2

Fig. 5: Priority 3

REFERENCES

[1] Computer-assisted analysis of spinal curvature parameters from CT images, Ján Barabáš, *IEEE*, 2012.
[2] The measurement of lumbar spinal curvature in Thai population: relationship to age, gender, and body mass index, Wisuchana Maicami, IEEE, 2014.
[3] SpineSeg: A segmentation and measurement tool for evaluation of spinal cord atrophy, Felipe P.G Bergo, IEEE, 2012.
[4] Determination of spinal curvature from scoliosis X-ray images using K-means and curve fitting for early detection of scoliosis disease, Bagus Adhi Kusuma, IEEE 2018.
[5] Improving Bug Localization with Character-Level Convolutional Neural Network and Recurrent Neural Network, Yan Xiao, IEEE, 2018.
[6] Node Identification in Wireless Network based on Convolutional Neural Network, Weiguo Shen, IEEE, 2018.
[7] Feature Correlation Loss in Convolutional Neural Networks for Image Classification, Jiahuan Zhou, IEEE, 2019.
[8] Convolutional Neural Network Approach to Lung Cancer Classification Integrating Protein Interaction Network and Gene Expression Profiles, Teppei Matsubara, IEEE, 2018.
[9] 3D ultrasound imaging method to assess the true spinal deformity, Quang N. Vo, IEEE, 2015.
[10] Simple convolutional neural network on image classification, Tianmei Guo, IEEE, 2017.
[11] Automatic segmentation of the spinal cord and intramedullary multiple sclerosis lesions with convolutional neural networks, Charley Gros, NeuroImage, 2018.
[12] Automated comprehesive Adolescent Idiopathic Scoliosis assessment, Wu H, MVC-Net Medical Image Analysis, 2018.
[13] Automated measurements of lumbar lordosis in T2-MR images, Ihssan S. Masad, decision tree classifier and morphological image processing Engineering Science and Technology an International Journal, 2019.
[14] 3D ultrasound imaging method to assess the true spinal deformity, Quang N. Vo, IEEE, 2015.
[15] Simple convolutional neural network on image classification, Tianmei Guo, IEEE, 2017.
[16] 3D ultrasound imaging method to assess the true spinal deformity, Quang N. Vo, IEEE, 2015.
[17] Detection and classification of lung abnormalities by use of convolutional neural network (CNN) and regions with CNN features (R-CNN), Shoji Kido, Advanced Image Technology, 2018.
[18] Determination of spinal curvture from scoliosis X-ray images using K-means and curve fitting for early detection of scoliosis disease, Bagus Adhi Kusuma, IEEE, 2017.
[19] Direct automated quantitative measurement of spine by cascade amplifier regression network with manifold regularization, Shumao Pang, Medical Image Analysis, 2019.
[20] Spatial Special Fusion with CNN for Hyper Spectral image super resolution, Xian-Hua Han, IEEE, 2018.

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