Spinal Region Segmentation for Intervertebral Distance of X-Ray Images Using Spectral Analysis

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Abstract

Physics plays a vital role in cultivating the knowledge of natural sciences and establishing the foundation of logistic and scientific method. The application of physics to medical sciences has been developed in practice for centuries. X-Ray, CT scan and MRI images of the spine provide a practical approach for detecting and assessing vertebral abnormalities. For accurate vertebra detection number of features of an image can be extracted and meaningful information can be obtain from low level information in the image using segmentation. In this paper a method is proposed for making treatment of spinal traction efficient and feasible by using image processing algorithm based on the data obtained from the survey and images of the patients.

Keywords: *Spinal Traction, Hough transform, segmentation,spectral transformation and Survey report.*

Introduction

With the time, as there is advancement in medical technology, there is also a huge increment in number of physical disabilities and diseases. Among them some are curable and some aren't. Now a day's researchers are more concerned in finding the cure of major diseases like Cancer, HIV AIDs, and Diabetes etc. But still there are some common problems which needs attention like Low back pain, disk herniation, sub-acute pain etc. As work load is increasing, problem of low back pain & sub-acute pain and issues related to spinal cord are also growing simultaneously. Ignorance of such pain becomes chronic disease which not only affect our spine, but also affect our work, afterwards it become major symptoms of disabilities. Low back pain is further classified as acute or sub-acute lower backpain and chronic lower back pain. Acute back pain generally last for 2-3 weeks because of which people don't give it much attention but chronic treatment of chronic lower back pain is too difficult, that even surgery can't provide permanent relief.[1][2]

The diagnosis and treatment of lower back pain, disk herniation, and muscular spasm, etc. thus become a major problem. Lumbar and cervical disk herniation is one of the most common causes of lower back pain and it is often caused in the weakest part of the disk i.e. posterolateral side.

Lumbar and cervical traction is most preferred treatment of lumbar and cervical disk herniation but its effectiveness as a part of physical therapy is a matter of discussion.

Literature Review: Research done in clinics indicates that disc is responsible for majority of lumber and cervical pains. Compression decreases intradisc space and increases pressure between intervertebral disc leading to annular compromise and possible extrusion of nuclear material[5].

Now a day's Traction using Decompression Therapy becomes an effective method of treatment in spinal traction. In the spinal decompression therapy, spinal disc can be isolated and negative pressure is applied by cycling through distraction and relaxation phases, this causes a vacuum effect within it.

Disc disorders are often connected to spinal trauma. Trauma arises in neck due to head injuries caused during accidents and falls. As the brain stem regulates the postural muscles of the spine, any injury in the upper portion of the neck can affect brain's normal control over the postural muscles, which leads to muscular weakness, atrophy and spasm throughout the neck and back.[6] Author gives a new approach in which two diagnostic tools are used for analysis of injuries in upper cervical region –Para spinal Digital Infrared Imaging and Upper Cervical Radiography . Magnetic Resonance Imaging is effective technique for detecting fractures, pseudo-arthrosis, and infections [7]. Three-dimensional imaging tests like MRI and CT scan, is ideal foranalyzing & visualizing pathology of the IVD (intervertebral disc), neural structures such as the spinal cord. Imaging method provide superior structural information and a better resolution[8]. Schmitz et al. [9] proposed a new method in which semiautomatic image analysis routine is used to analyze dendrite and synapse characteristics in immune-fluorescence images. Another method effective in reducing pain or improving intervertebral motions is HVLA-SM(High velocity low amplitude spinal manipulation)[10].

Objective: As X-ray image of spine are very noisy and of low contrast, the extraction of geometric features from images is very common problem. Over the years, several different approaches have been devised to extract these features. In present scenario the treatment(traction) given for spine problems is based on the experiences of physiotherapist and the ranges predefined in literature. Sometimes the treatment becomes inefficient and also cause several other adverse effect. In present scenario none of the method used for treatment combined images and physics together. The key objective of this research is to develop an algorithm for efficient traction treatment using image processing algorithm. With the help of this algorithm we will be able to calculate the exact amount of force which is required, after considering the age, weight and other factors, to fulfill the treatment of spinal traction. This will provide accuracy and efficiency in the methodology of traction treatment applied.

a. The traction therapy will be more accurate & efficient.

b. It will be economical as the number of therapies to be provided would be less thus reducing the charges to be paid multiple times.

Survey Report: To find the accuracy of traction treatment a small survey is conducted under which data of 84C-spine vertebras were collected and studied. Following observations are mention below:

For cervical traction the force to be applied is. 1/7th part of body weight and for lumbar traction the force applied i.e. 1/3rd of body weight as per defined in various literature. The following data were taken from Narmada Trauma Centre(Bhopal) and Rajiv Gandhi Hospital (Trilanga, Bhopal).

Table 1 Survey Report of Some Patients Who were Going Under The Treatment of Traction.

Patient Number (Male/Female)	Age of patient (in years)	Body Weight (in kg)	Type of traction	Applied Weight (in kg)
Patient 1 (Male)	42	65	Cervical	7
Patient 2 (Female)	40	55	Lumbar	20
Patient 3 (Male)	35	55	Cervical	6
Patient 4 (Male)	57	68	Cervical	8
Patient 5 (Female)	24	58	Cervical	6
Patient 6 (Female)	23	62	Cervical	6
Patient 7 (Male)	40	52	Cervical	6
Patient 8 (Female)	55	70	Cervical	8
Patient 9 (Female)	51	75	Lumbar	25
Patient 10 (Male)	51	90	Cervical	10
Patient 11 (Female)	560	70	Cervical	5
Patient 12 (Male)	50	75	Cervical	8
Patient 13 (Male)	23	59	Cervical + Shoulder pain	8
Patient 14 (Male)	42	60	Cervical	2
Patient 15 (Male)	55	60	Lumbar	20
Patient 16 (Male)	55	75	Lumbar	25

This data leads to us to do work for the improvement of traction treatment.

Methodology

Detection of accurate vertebra is most important for efficient spinal column diagnosis. In this paper we focus on one section of the spine i.e cervical spine. Primary objective of this research is to find intervertebral posterior height using image processing algorithms. The proposed approach is the hybrid approach in which the results obtained from image processing algorithm is combined with the physics behind the traction therapy, inorder to develop an generalized approach to calculate exact amount of force which is to be given to patient in case of cervical traction.

The intervertebral disc(IVD) is comprised of three distinct components: (a)the annulus fibrosus, (b) the nucleus pulposus, and (c)the cartilaginous endplates. The annulus fibrosus is the tissue of the intervertebral disc that surrounds the nucleus pulposus and forms the outer portion of the disc. Due to compressive load the posterior section of the intervertebral disc will undergo tension loading that causes the annulus to contract toward the center of the disc (White and Panjabi, 1990).

Table 2: Shows the intervertebral height for cervical spine

Study	IVD Height	C23	C34	C45	C56	C67	C7T1
Gilad and Nissan, 1986	Anterior	4.8 mm	5.3 mm	5.5 mm	5.4 mm	5.2 mm	4.7 mm
	Posterior	3.4 mm	3.3 mm	3.0 mm	3.0 mm	3.3 mm	3.5 mm
Przybylski et al, 1998	Anterior	5.2 mm	5.3 mm	5.2 mm	4.6 mm	4.9 mm	
	Posterior	3.4 mm	3.4 mm	3.7 mm	3.9 mm	4.3 mm	

Due to load, the intervertebral posterior height reduces. In this research, image processing algorithm are used to detect the intervertebral posterior height. If the intervertebral space is less then 3mm, mathematical algorithm runs to calculate the amount of traction force that is to be applied on the patient under medical supervision.

The proposed method consists of the following steps that will be applied to spinal images .a. Pre-processing stage includes- image acquisition, region localization (RL) and region localization enhancement.b. Shape boundary representation and segmentation stage-include GHT(Generalized Hough transform)

Performance Measures: Statistical parameters to calculate the performance of a binary classification are Sensitivity and specificity.

Standard formulas were used to measure accuracy, sensitivity and specificity.

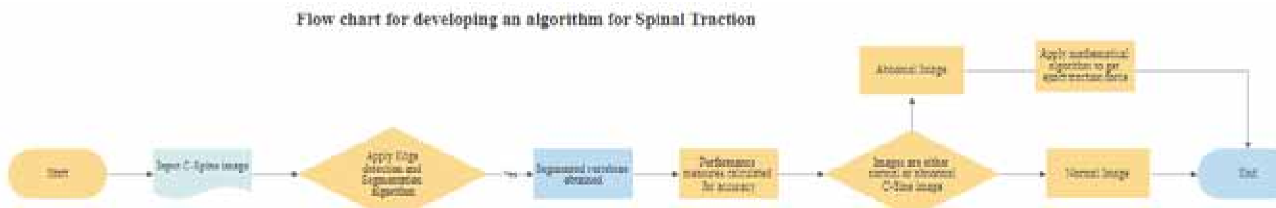
$$ACC = \frac{(TP + TN)}{(FP + TN) + (TP + FN)}$$

$$\text{Sensitivity} = \frac{TP}{(TP + FN)}$$

$$\text{Specificity} = \frac{TN}{(FP + TN)}$$

Jaccard Coefficient: The Jaccard coefficient measures similarity between finite sample sets, and is defined as the size of the intersection divided by the size of the union of the sample sets

Dice Coefficient: The Sorensen–Dice index, is a statistic used for comparing the similarity of two samples.



RESULTS

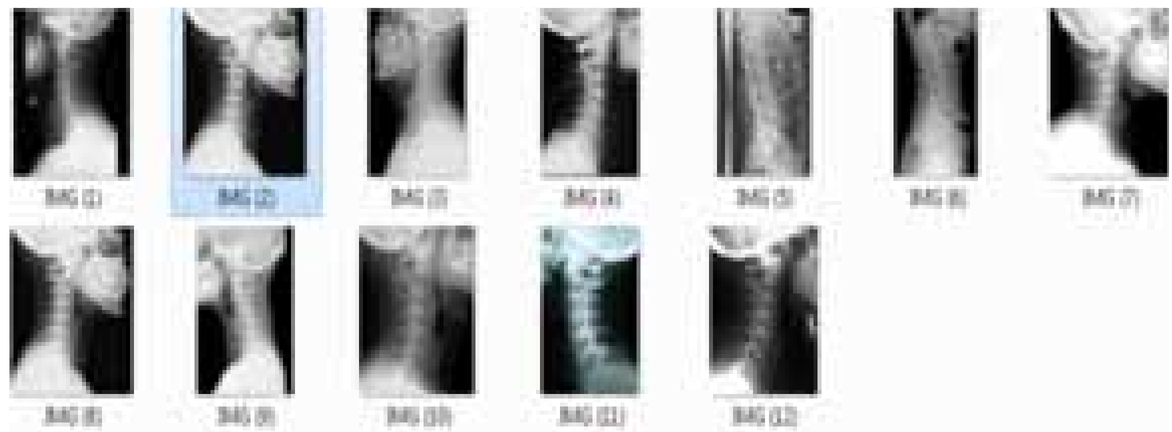
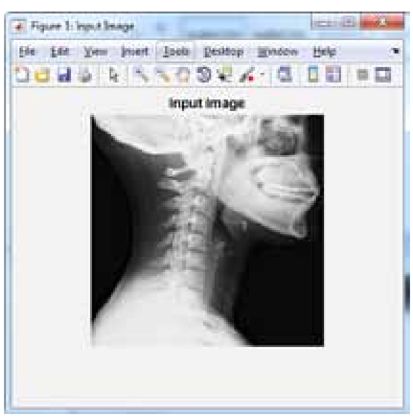
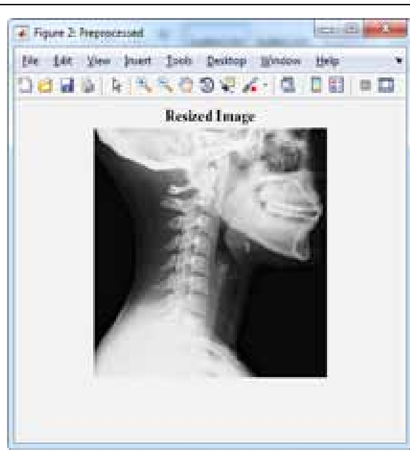
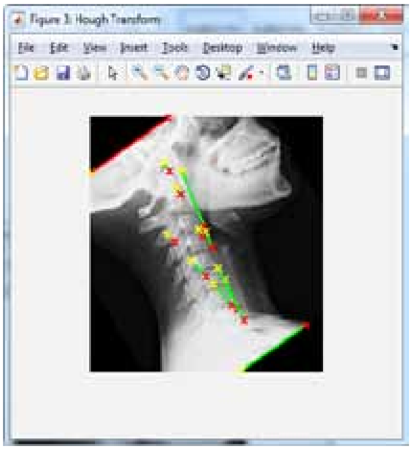
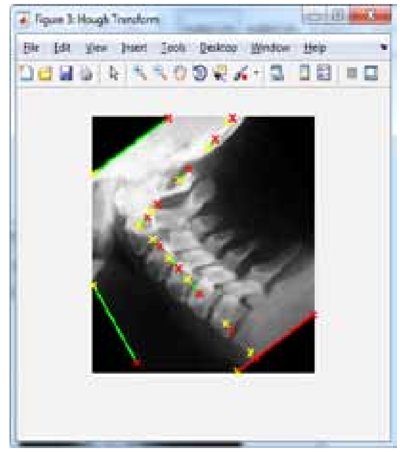
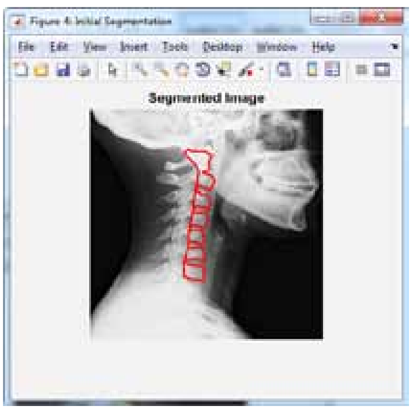
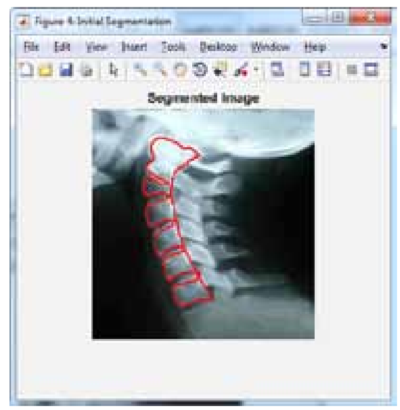
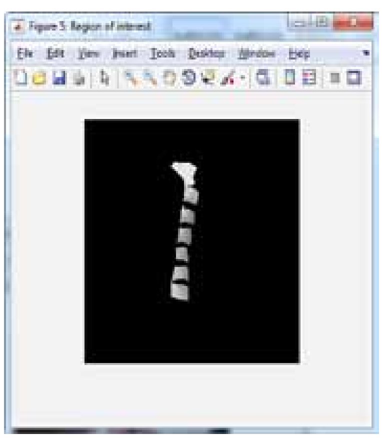
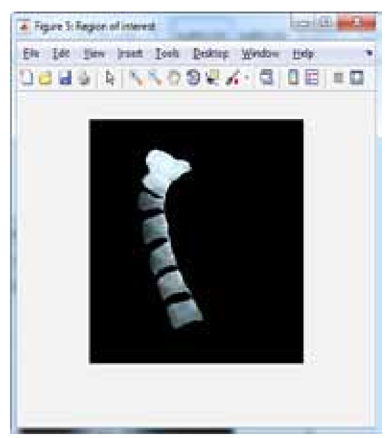
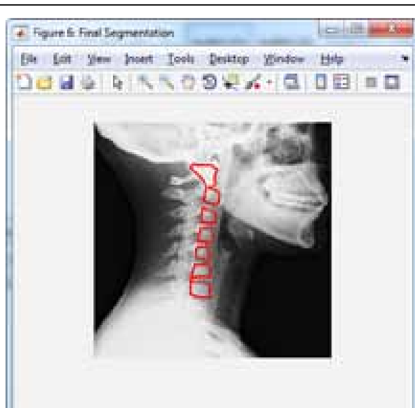
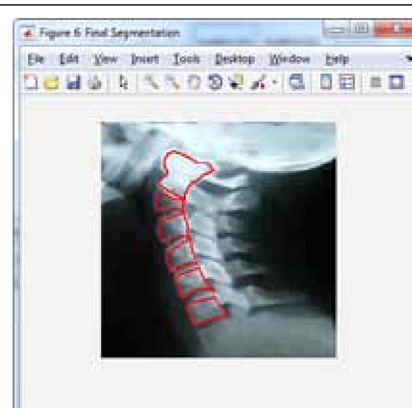


Fig. 3: Image database in Matlab

Normal image	Abnormal Image
	
	

Normal image	Abnormal Image
	
	
	
	

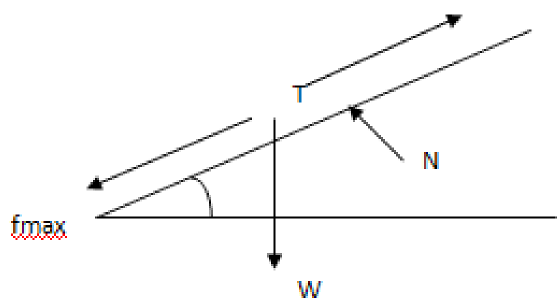
Normal image	Abnormal Image
Sensitivity : 97.410021% Specificity : 100.000000% Correct Classification : 97.434998% == Jaccard coefficient : 97.434998 % Dice coefficient : 98.700837 % == >> >> C2 & C3 = 1.3189 C3 & C4 = 3.3357 C4 & C5 = 3.4211 C5 & C6 = 3.5403	Sensitivity : 95.165947% Specificity : 100.000000% Correct Classification : 95.350647% ==================================== Jaccard coefficient : 95.350647 % Dice coefficient : 97.619996 % ==================================== >> C2 & C3 = 0.87963 C3 & C4 = 0.82671 C4 & C5 = 0.98839 C5 & C6 = 1.1337

Fig. 4: Results of image analysis

Result Analysis

Fig 4 shows that in abnormal cervical image the intervertebral posterior height calculated is less then 3mm. In such condition an algorithm is applied in order to calculate traction force which may be applied to the patient under medical supervision.

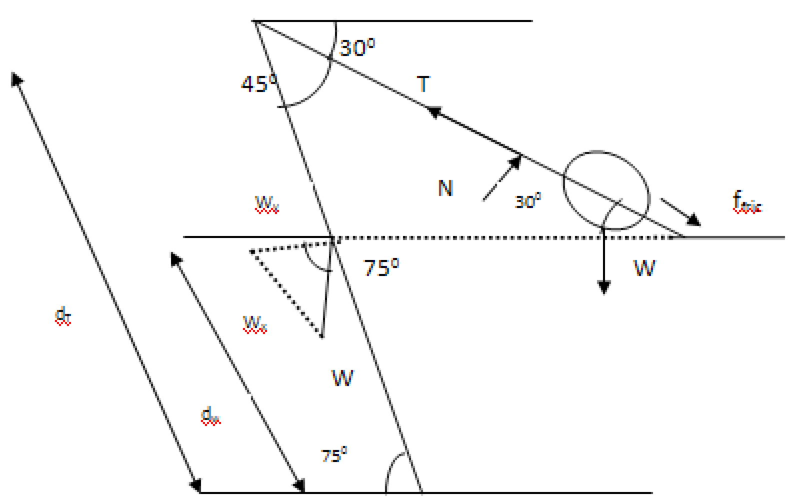
Mathematical calculation



$N = w\cos 30^0$

$T = fmax + W\sin 30^0$

$Fmax = \mu N$



Free body diagram of traction machine setup

Below calculations are based on the traction machine setup,. i.e distance from ground, machine weight and total height.

The cervical traction is applied to a patient; traction force is developed in backward while maintaining the system in equilibrium.

Machine weight =15 kg

Center of mass height from ground= 102cm (max)

If the distance from bottom to the center of mass is 102cm, then the total height from where force is applied is 173cm as distance from bottom to the center of mass 59% of total height.

From the free body diagram establishing momentum equation about the bottom

$T_y.d_T=W_y.d_w$

Where:the distance from the bottom to the center of mass is

d_W=59% of 1.73m =1.02m and

d_T= 85% 0f 1.73m = 1.46mtherefore

$T_y.d_T=W_y.d_w$

$Tsin45^0.d_T = W_y.d_w$

$(fmax +wsin30^0)sin45^0*1.46 = Wcos75^0*1.02$

As $fmax = \mu.N$

In this paper for two body weight of a patient calculations are done

Body weight is 70kg and 75kg, so head weight i.e 8% of the total body weight are 5.6kg and 6kgs respectively.

$(\mu.N + wsin30^0)sin45^0* 1.46 = Wcos75^0*1.02$

Where $N = Wcos30^0$,here w is weight of the head of a patient

And the value of $\mu = 0.2$

Now equating the values in the equation

$(\mu. Wcos30^0 + wsin30^0) sin45^0x 1.46 = Wcos75^0x1.02$

$(0.2*5.6cos30^0+ 5.6sin30^0) sin45^0* 1.46 = Wcos75^0*1.02$

The exact W i.e traction weight can be calculated as

$$W = \frac{[(0.2*5.6cos30^0+ 5.6sin30^0) sin45^0* 1.46]}{cos75^0*1.02}$$

W= 14.7kgs

Accuracy recognition comparison between the study of Gilad & Nissan, 1986, Przybylski et al,1998 and Present Research.

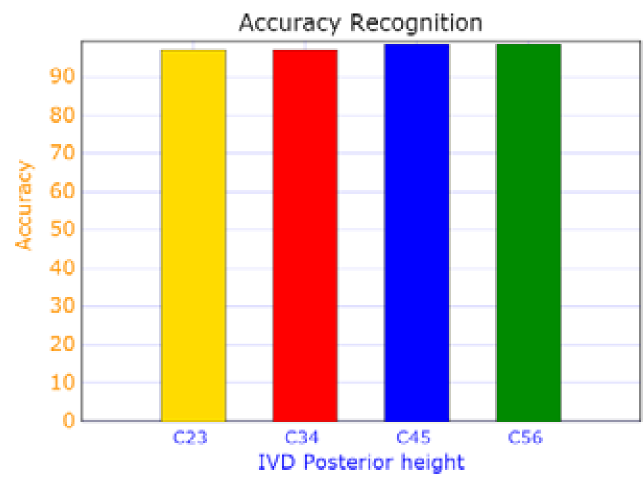


Fig 5: Accuracy Recognition Chart

Discussion

As discussed earlier, the current methodology of applying traction is not the accurate method as not all the parameters are considered while applying force on the body. This method at present is just based on hit and trial which can be done by the experienced physiotherapists only, as there is a huge probability of error if practiced by any inexperienced doctor. The machines that are used to apply weight during the therapy simply apply force, fed to them as an input by the therapist, which is calculated on the basis of body weight, age and sex of the patient. Hence this therapy need some changes for improvement, in medical practice to improve decision-making by matching a treatment to a specific sub-group of patients Clinical prediction rules (CPR) are commonly used [11]. To make it more efficient and accurate method for experienced as well as inexperienced physiotherapists to study. The force applying machines should work automatically on the basis of the patient's physical status and not much interference, in calculation, of the therapists should be involved. A user-friendly interface will be also built for usability improvement and enhancement[12].

Conclusion

On the basis of this algorithm machines can also be designed which can apply calculated force automatically. Thus reducing manual work and reduction in manual interference will lead to lesser error in the traction process.

Future Scope: A Clinical prediction has been developed which will improve decision-making and reduce time & cost[11]. Considering the advantages (feasible, accurate and economic) of the goal, if achieved, this may be used to develop traction machines in future which will be algorithm based and would work automatically on the basis of the factors to be considered while applying the therapy. This will also reduce the duration and frequency of treatment to be applied to a patient.

Ethical Clearance: Dataset have been collected from hospital, no involvement of human subject is done in research. LOR is received from Rajiv Gandhi Physiotherapy College, Bhopal

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Conflict of Interest: nil

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