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AUTOMATED ESTIMATION OF NECK MOVEMENT ANGLES USING IMAGE PROCESSING TECHNIQUES

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Abstract: Neck and spinal movements are a major area of study relating to causes for pain and injury. Kinetic behaviour of the vertebral segments form an important aspect of biomechanics. Most of these studies concentrate on neck flexion, extension and translation. These studies are useful in applications that model complicated child births by monitoring the head and neck movement of the baby. Image Processing techniques accompanied by coordinate geometry yields promising results in estimating these movements. In our study, manual entry of data is replaced by automated selection of pixels based on the chosen region of interest (ROI). The primarily used image processing concepts involve ROI based processing and edge detection. The results show better accuracy with automated selection of pixel points and the error rate is quite low. The difference between manual and automated measurements is 5.55% for neck flexion angle and about 14% for the neck extension angle.

Keywords: Biomedical Images, Cervical images, Flexion, Extension, Region of Interest, Edge detection

I. INTRODUCTION

One of the major medical problems encountered in today's modern societies is neck, or cervical spine pain [1]. These aches have various causes. Flexion-extension X-rays are commonly used clinically to assess stability of the cervical spine for abnormal motion. Spinal instabilities are usually the result of ligamentous incompetency. These changes allow the vertebral segments increased motion with potentially catastrophic results to the spinal cord. Diagnosis and treatment decisions are made, in part, based on the clinician's assessment of these X-rays [2],[3]. Numerous techniques have been developed to evaluate for increased/aberrant motion of the spinal and neck segments. The relatively recent introduction of flexion/extension MRI's suggests a similar mensuration could be applied to this modality.

Estimation of these causes can be made easier for a physician by evaluating various angles and distances involved in neck movement. In anatomy, flexion involves a coupled motion of anterior rotation and anterior translation in the sagittal plane. Extension involves Sagittal plane posterior axial rotation and posterior translation. If horizontal lines were drawn at the mid-body of adjacent vertebrae, normal flexion would involve the intersection of these lines in anterior to the spine, and normal extension would see an the angle formed posterior to the spine. The current study involves an initial investigation into the measurement of neck movements on flexion/extension MRI. Often, direct observation of X-ray or MRI images involve inter-observer disagreements. Hence, a completely computer assisted estimation of the angles could reduce ambiguity [2].

With the advancement in medical imaging technology, medical images are playing a vital role in surgery and diagnosis. Region of Interest (ROI) usually means the useful and meaningful part in an image. It is a neuropsychological concept which means the regions that people are concerned with. ROI extraction is of great use in biomedical applications - such as in detection of cancerous cells, polyps, osseous abnormalities, calcifications and other abnormalities. We perform ROI in order to reduce the amount of complexity involved in processing the overall image. It also enhances efficiency by reducing computation time. Modern and future diagnosis and surgery rely on medical images and software to assist practitioners such as in computer-aided diagnosis, surgical planning, simulation, and robotically assisted surgical interventions [4], [5]. Moreover, working with biomedical images is more complex than normal images as they are fuzzy and contain more noise.

Edge detection is a predominantly used concept in computer vision and image processing and is being employed in our study to extract the boundaries of the ROI. Edge basically refers to the set of pixels whose intensities show a step change or rooftop change and it exists between objects and background, objects and objects, regions and regions and elements and elements. It is useful in image segmentation and characterizes discontinuities in images. There are different operators that can be used for edge detection viz., Canny, Prewitt, Sobel, Laplacian of Gaussian, Differential operator etc. Sobel Operator is used in our study and is one of the most efficient edge detection masks [6].

In this study, we select the neck region (ROI) extending into the vertebral column in two different positions. Case 1 uses vertical and flexed positions and Case 2 uses vertical and extended positions. We aim at determining the angle between the two positions of the neck in each case. Also, the process is mostly automated.

II. PROCEDURE

A: Manual Estimation of Neck Flexion and Neck Extension Angles

Our study involves the comparison of estimation of neck flexion and extension angles using manual and automatic methods. The manual method involves the entry of pixel data by the user. A set of points are selected using the data cursor of 'imtool' Graphical User Interface in MATLAB. These points are chosen alternatively on the left and right boundaries of the ROI (neck/vertebral region) by placing the data cursor at the required point. In the case of each coordinate pair, their midpoint is computed and a best fit line is generated through these midpoints using 'polyfit' command. We estimate the angle made by the line generated with respect to a perpendicular line (normal resting position of the neck) using the three points that make the triangle. The angle made at the intersection of the two lines is calculated as:

$$\tan(\theta) = \text{perpendicular/base} \qquad \text{----(1)}$$

where θ is the angle of intersection of the two lines and represents the neck flexion angle (see fig. 4).

B: Measurement of Neck Flexion Angle using automatic method

The complete code is written using MATLAB Version 7.6.0.324 (R2008a). Initially we select the region of interest which is done interactively by tracing the boundary of the region under concern. A filter mask is generated based on the area selected. In our case the neck region is the area under concern. We specifically concentrate on the neck vertebrae where flexion begins. This mask converts the original true color image to a binary image. In Case.1 we select the ROI for a neck flexion image as shown in fig.1a and generate a normal with respect to the flexed position of the image. Fig.1b shows the binary image generated after the ROI is selected using the mask.

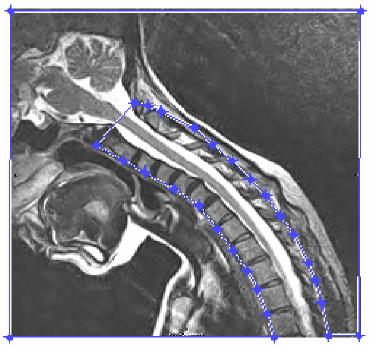


Figure.1a: Mask used for selecting

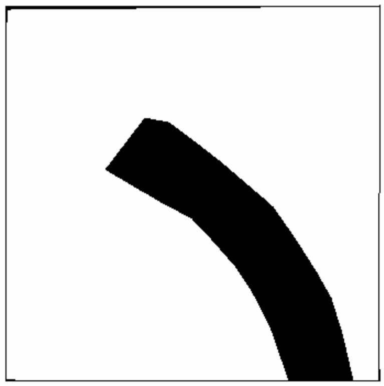


Figure.1b: Binary ROI after masking the ROI in an image showing neck flexion

The ROI in Fig.1b is cropped to select only the essential area in order to reduce computational complexities. Also, the presence of unnecessary data may be a factor in influencing the generation of the best fit line. Fig.2 shows the cropped ROI. We observe that the grey level intensity of the selected area is '0' while the surrounding region has a grey level intensity '1'as the image is binary. Using this property, we randomly determine 1000 points on this area and generate a best fit line through these points using the 'polyfit' command. As we increase the number of points selected, the accuracy of the best fit line increases.

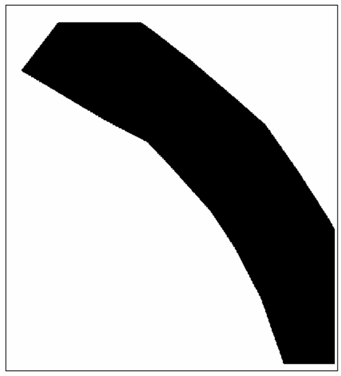


Figure.2: Cropped ROI image from which points are selected

A vertical line is generated at the point needed by entering manually the x and y coordinates of the points. The angle of intersection is estimated using the properties of a triangle as in the manual method. The tangent of an angle is calculated using equation 1.

C: Measurement of Neck Extension Angle using automatic method

We apply an ROI mask to interactively select the area under concern as shown in Figs.3a. The binary mask for the extended neck position is shown in Fig 3b. We now detect the edge or boundary of the neck position in the extended position. Thus the boundary of the ROI alone is having a gray level intensity 1(binary image). The left and right boundaries of the vertebra alternately contribute one pixel to the array containing all pixels with intensity 1. Thus, we compute the midpoint of each pair and generate a best fit line through these midpoints. In this case, the angle of intersection with respect to the normal resting neck position is calculated using equation (1). Here, again we use

$$y=m*x+c,$$

For each set of data points. 'y' represents the y-coordinate, m is the slope of the line, 'x' is the x-coordinate and 'c' is the y-intercept to evaluate the equation of the line.

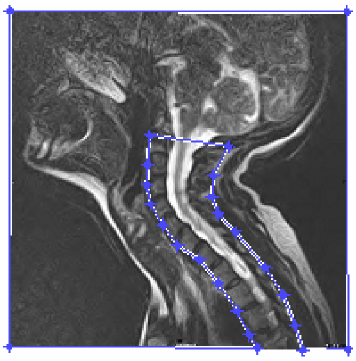
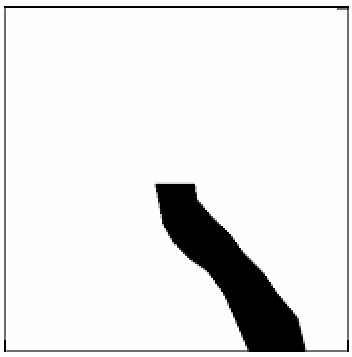


Figure.3a: ROI selection for the extended neck position



\Figure.3b: ROI binary mask for the extended neck position

Here, again the points on the ROI are computed automatically without having to select any points on the boundary.

III. RESULTS

A: Measurement of Neck Flexion Angle

Fig.2 is used to select the required points randomly and automatically. These points are generated using 'randperm' command in MATLAB. The best fit line through the vertebra is generated and the angle of intersection is estimated using the three coordinates that make up the triangle as shown in Fig.4.

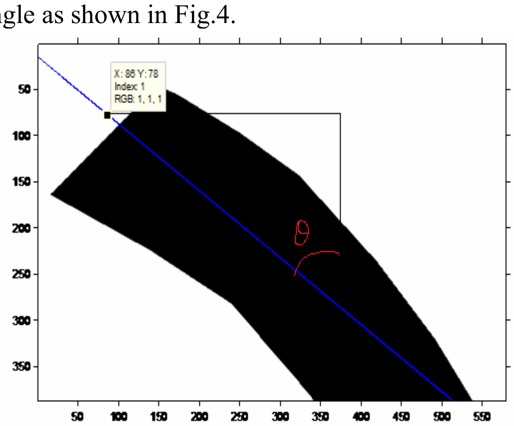


Figure.4: Best fit line through flexed neck position for estimation of neck flexion angle

The estimated angle of intersection in manual method is 50.9 degrees and the angle using automated method is 53.9 degrees. Thus the percentage error between the manual and automated method is 5.55%.

B: Measurement of Neck Extension Angle

Fig.5 represents the best fit line through the edge detected ROI of the extended neck. The angle is estimated using the three coordinate points that make up the triangle. The neck extension angle computed manually is 34.8 degrees and the automatically estimated angle is 40.2 degrees with an error of 13.68%.

This error can be minimised by including larger number of points on the ROI and making the ROI more precise by cropping. However the performance is quite good in the example above as the error rate is reasonable.

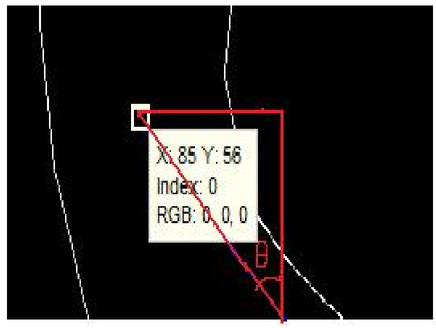


Figure.5: Best fit line through edge detected ROI of the extended neck for estimation of neck extension angle

IV. CONCLUSION

This study successfully estimates the neck flexion angle and neck extension angle using ROI selection and coordinate geometry. The process is automatic in estimating the angles thus reducing human intervention. This study proves to be useful in diagnosing neck and spinal instabilities, simulating child birth in complicated deliveries, etc [7]. The angles are measured accurately and the error percentage compared to the manual method is 5.55% and 13.68% respectively for Case.1 and 2. This study can be further extended by choosing larger number of data points on the ROI. However, this increases simulation time. Using similar techniques, future work can involve the estimation of translation distance of the neck.

V. REFERENCES

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