LUMBAR SPINE MOTION ANALYSIS VIA AUTOMATIC SEGMENTATION

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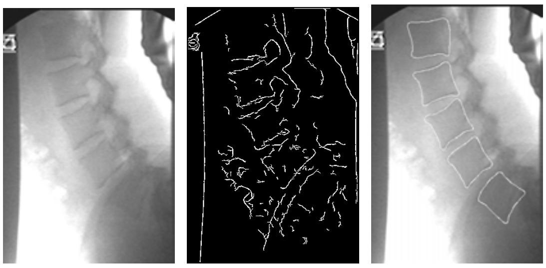
INTRODUCTION

Low back pain is a very common problem and the consequent cost is enormous. In spite of its prevalence, however, it is still difficult to obtain accurate diagnosis. Mechanical disorder is now often regarded as the main cause. Presently, a number of studies are directed at measurement of spine kinematics. Since the lumbar spine is a deep-rooted structure, this has been difficult until digital videofluoroscopic (DVF) imaging was developed [Breen et. al. 1989]. In this paper, DVF is used to acquire the motion sequence of the lumbar spine, to solve the problems with manual location of the vertebrae within the sequence, a spatio-temporal Hough transform (STHT) [Zheng et. al. 2001] has been developed to automatically locate vertebrae in DVF images and results of tests are very promising.

METHODS

During DVF image acquisition, the subject lies on a table which can be moved at a controlled rate. A major advantage of DVF is that it can capture a whole motion sequence with a radiation dose that is lower than a single X-ray plate of the lumbar spine. This reduction, however, incurs deteriorated image quality and causes problems with edge detection. Phase congruency [Kovesi 1999], which detects edges by phase information, is used here for improved edge detection. Phase congruency has significant advantage over most of the gradient-based methods as it can cope with uneven contrast and brightness within the image. Fig. 1 (b) shows convincing results in L5 edge (L*n* is the *nth* vertebra of the lumbar spine).



(a) (b) (c)

Figure 1: DVF image, edge map and extraction results.

The Hough transform (HT) is a powerful tool in computer vision for extracting objects in images by evidence gathering in a parameter space [Leavers 1993]. Here an STHT has been developed to locate five lumbar vertebrae in each frame of a selected sequence while the subject moves from a neutral position into flexion, then back through neutral to extension, and finally to neutral position. The new STHT differs from the traditional HT in that it considers not only the parameter space, but also the spatio-temporal information, that is, the relationships between vertebrae within a single frame as well as throughout the whole sequence. However, the huge search space involved leads to increased computational cost. To solve this problem, a genetic algorithm [Goldberg 1998] is employed to find the optimal values of a "fitness function" which is the combination of the two terms discussed above. Aided by the spatio-temporal information, the STHT can provide us with more robust results. Fig. 1 shows a DVF image, its edge map and vertebral extraction results.

RESULTS

The extraction results from the STHT enable us to conduct further kinematic study of the lumbar spine. Fig. 2 shows the motion pattern in the *x* direction of the centers of five lumbar vertebrae moving from full flexion to extension, and reveals a sinusoidal feature. In data acquisition the interface between the moving lower and the static upper sections of the table was at the level of L3. This is to maximise the focus on the whole lumbar spine. It explains why L3 moves less than the other four segments.

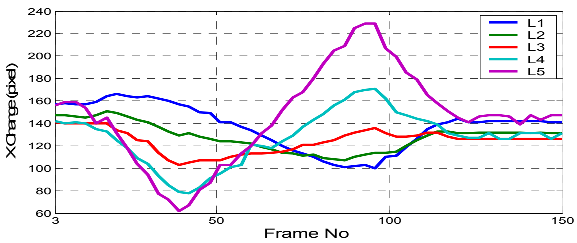


Figure 2: Motion pattern of the lumbar spine.

CONCLUSION

Our method shows potential for automatic extraction of the vertebrae in moving DVF images of the lumbar spine. We are currently applying this to a large database of spine motion from which the kinematics at the segmental level will be produced. Further validation studies using a calibration model are also being undertaken.

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