THE UNIVERSITY OF QUEENSLAND

Electromagnetics and Imaging
School of ITEE
The University of Queensland

Southern X-Ray Clinics

qcif

QCIF Technology Diffusion Project
Progress Report 2, November 2007

1. Project Identification

1.1 Administering Organisation

The University of Queensland

1.2 Project Title

Segmentation of Thoracolumbar Muscles from MRI: Morphometric Analysis and 3D Visualisation.

1.3 First-named participant

Name	Dr Craig Engstrom
Email address	craig@hms.uq.edu.au
Telephone	3365 6381

1.4 Other participants

Name	*Institution*
Dr Andrew Mehnert	The University of Queensland
Prof Stuart Crozier	The University of Queensland
Dr Stephen Wilson	The University of Queensland
Dr Duncan Walker	Southernex Imaging Group

2 Project Description and Objectives

2.1 100 Word Project Summary

Detailed morphometric data on the thoracolumbar muscles are crucial for biomechanical and clinical investigations into lumbar spine injury and low back pain, which affects over 70% of people during their life. Magnetic resonance imaging (MRI) is frequently used for morphometric analyses of the thoracolumbar muscles although current investigations involve time- and expertise-intensive *manual* segmentation of the numerous, architecturally complex trunk muscles. To enable large-scale, quantitative studies on the thoracolumbar muscles for use in routine clinical settings, *automated* software for fast and robust segmentation is required for extraction of accurate, *objective* morphometric data such as muscle volume and physiological cross-sectional area.

2.2 Summary of original objectives

This project will develop automated software, implementing novel algorithms based on domain-specific knowledge, for performing objective morphometric analyses and 3D visualisation of the thoracolumbar muscles derived from MRI data. In particular, the algorithms / software will enable rapid automated segmentation of the thoracolumbar muscles, co-registration of serial MR examinations and 3D rendering / visualisation of

segmented muscles. The outcomes of this project will expand the clinical imaging services offered by the industry partner, Southernex Imaging Group and have the potential to lead to commercially valuable intellectual property.

3 Project over Duration of Funding

3.1 Have there been changes to the project (yes/no)? If yes, give details.

No

3.2 What were your research plans and objectives for the period covered by this Report?

This report covers the period coinciding with the first six months of funding. The basic research plans and objectives for this period included i) the continued generation of a dataset of manually segmented individual thoracolumbar spine muscles to establish "ground truth" for ii) the development of an atlas-based segmentation methodology. Initially, we are focusing our attention on the quadratus lumborum (QL), a paraspinal muscle with a complex architecture in which we have recently reported an association between QL volume asymmetry and stress fractures of the lumbar spine in cricket fast bowlers [1].

3.3 Did the research project proceed as planned? What have you achieved over this period?

The project is proceeding as planned with the collaborative involvement of our multidisciplinary team of Engstrom (ITEE, HMS), Mehnert (ITEE), Crozier (ITEE), Walker (Southernex), Jurcak (PhD, ITEE) and Fripp (UQ, CSRIO). The progress of the research project to date is summarized below and is the basis for a recently submitted abstract to the 2008 International Society for Magnetic Resonance in Medicine conference in Canada [2]:

1. Full volumetric analyses of the QL muscle based on detailed manual segmentation of MRI examinations from the lower thoracic lumbar spine (contiguous 7mm axial SE images) have been completed for ~20 subjects.

2. Automatic Segmentation of QL – the research project to date has progressed successfully incorporating the following:
   - pre-processing of the MRI dataset with a customized 3D bias field correction algorithm, adapted from [3], to correct signal inhomogeneities across the paraspinal muscles, including QL, and surrounding tissues;
   - pre-processing of the original 7mm axial images with a partial volume estimation algorithm, adapted from [4], for interpolation of thinner slice thicknesses to obtain improved voxel resolution of 0.98x0.98x3.5mm;
   - development of a series of initial shape-based atlases created iteratively based on the approaches presented in [5], using affine [6] and non-rigid registration [7] methods (Figure 1);

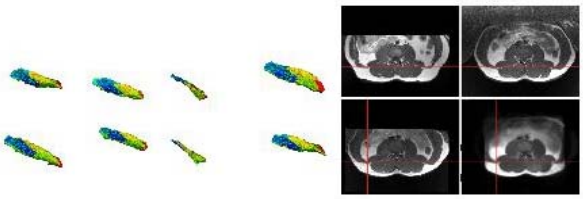

Figure 1. Left - Initial shape-based models of QL. Right - Affine and non-rigid registration of QL.

- automatic segmentation of the QL for individual subjects based on affine and non-rigid registration of the average probability atlas (Figure 2) propagated onto each case to allow comparison with the volumetric data obtained from manual segmentation using the Dice coefficient.

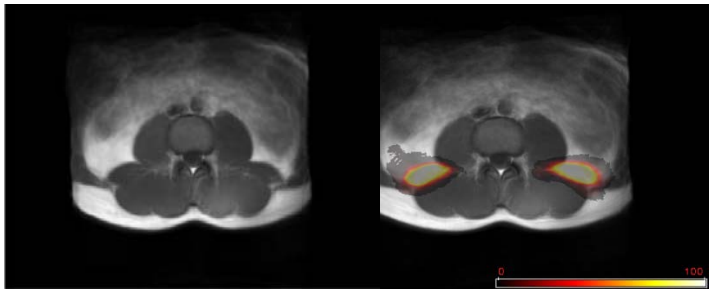

Figure 2. Axial view of the average Atlas (left) and same Atlas overlaid with probabilistic map of segmented QL (right).

References:

[1] C. M. Engstrom, D. G. Walker , V. Kippers, and A. J. H. Mehnert "Quadratus Lumborum Asymmetry and L4 Pars Injury in Fast Bowlers: A Prospective MR Study" MEDICINE AND SCIENCE IN SPORTS AND EXERCISE 39 (6) pp. 910-917 JUN 2007

[2] V. Jurcak, J. Fripp, C. Engstom, B. Coe, O. Salvado, S. Ourselin, S. Crozier (submitted). "Atlas based segmentation of Quadratus lumborum using non-rigid registration on Magnetic resonance images of the lower back". International Society for Magnetic Resonance in Medicine

[3] O. Salvado, C. Hillenbrand, S.X. Zhang, D.L. Wilson "Method to correct intensity inhomogeneity in MR images for atherosclerosis characterization" IEEE TRANSACTIONS ON MEDICAL IMAGING 25 (5) pp. 539-552 MAY 2006

[4] O. Salvado, C. M. Hillenbrand, D. L. Wilson "Partial volume reduction by interpolation with reverse diffusion" INTERNATIONAL JOURNAL OF BIOMEDICAL IMAGING 2006 Article ID 92092, 13 pages, 2006.

[5] T. Rohlfing, R. Brandt, R. Menzel, C. R. Maure "Evaluation of Atlas Selection Strategies for Atlas-Based Image Segmentation with Application to Confocal Microscopy Images of Bee Brains" NEUROIMAGE 21 (2004) (4), pp. 1428–1442 JUN 2004

[6] S. Ourselin, A.R. et al, "Reconstructing a 3D structure from serial histological sections", IVC 19 (2001) 25-31

[7] D. Reuckert, L. I. Sonoda, C. Hayes, D.L. Hill, M. O. Leach, D. J. Hawkes "Nonrigid registration using free-form deformations: application to breast MR images" IEEE TRANSACTIONS ON MEDICAL IMAGING 18 (8) pp. 712-721 AUG 1999

3.4 Have you experienced any difficulties that have affected the progress (yes/no)? If yes, give details.

No

3.5 What are your research plans and objectives for the coming quarter?

- Ongoing development of the atlas-based segmentation methodology for morphometric analyses of the paraspinal musculature will involve steps such as an expansion of the MRI dataset and analyses based around the selective incorporation of tissue classifiers with the statistical shape models to augment localized boundary segmentations between muscles and surrounding soft-tissues.
- We will port our existing code to QCIF's SGI Altix 3700 Bx2 (64 processors) to take advantage of parallel processing to perform non-rigid registration of the expanding number of large MRI datasets (currently ~20 subjects).

4 Certifications

4.1 Certification by first-named investigator

I certify that:

- This is an accurate progress report for the period covered; and
- All named investigators are in agreement that this report is an accurate representation of the current progress of the project.

1st-named Investigator signature_____

Date_____