Automated laser registration and quantitative assessment of articular cartilage for computer assisted orthopaedic surgery

JOSHI SV1, ROWE PJ1, PIERCE G2, AHMED KE3, MACLEOD C2

1Department of Biomedical Engineering, University of Strathclyde, Glasgow, UK
2Centre for Ultrasonic Engineering (cue), Department of Electronic & Electrical Engineering, University of Strathclyde, Glasgow, UK
3University of Glasgow Dental School, Restorative Dentistry Department, Glasgow, UK

shailesh.joshi@strath.ac.uk

Over the last decade Computer Assisted Orthopaedic Surgery (CAOS) has emerged particularly in the area of minimally invasive Uni-compartmental Knee Replacement (UKR) surgery. Image registration is an important aspect in all computer assisted surgery including Neurosurgery, Cranio-maxillofacial surgery and Orthopaedics. It is a process of developing a spatial relationship between pre-operative data, such as Computerised Tomography (CT) scans or Magnetic Resonance Imaging (MRI) scans and the physical patient in the operation theatre. It is possible for example to visualise the patient’s medial or lateral condyle on the tibia in the pre-operated CT scan as well as to locate the same points on the actual patient during surgery using intra-operative sensors or probes. However their spatial correspondence remains unknown until image registration is achieved. Image registration is the process that generates this relationship and allows the surgeon to visualise the 3D pre-operative scan data in relation to the patient’s anatomy in the operating theatre. Current image registration for most CAOS applications is achieved through probing along the articulating surface of the femur and tibial plateau and using these digitised points to form a rigid body which is then fitted to the pre-operative scan data using a best fit type minimisation. However, the probe approach is time consuming and therefore costly. It can often take 10-15 minutes to complete. Thus the rationale for this study was to develop a new, cost effective, contact-less, automated registration method which would entail much lesser time to produce the rigid body model in theatre from the ends of the exposed bones. This can be achieved using 3D scans taken intra-operatively using a Laser Displacement Sensor.

A number of techniques using hand held and automated 3D Laser scanners based on Triangulation principle for acquiring geometry of non-reflective objects have been developed and used to scan the surface geometry of a porcine femur with four holes drilled in it. The distances between the holes and the geometry of the bone were measured using digital vernier callipers as well as measurements acquired from the 3D scans. These distances were measured in an open source package MESHLAB version 1.3.2 used for the interpretation, post-processing and analysis of the 3D meshes. Absolute errors ranging from 0.1 mm to 0.4 mm and the absolute percentage errors ranging from 0.48% to 0.75% were found. Additionally, a pre-calibrated dental model was scanned using a 650 nm FARO™ Laser arm using the global surface registration approach in Geomagic Quality package and our 3D Laser scanner. Results indicate an average error of measurement of 0.16 mm, with deviations ranging from 0.12mm to -0.13mm and a standard deviation of 0.2mm. We demonstrated that by acquiring multiple scans of the targets, complete 3D models along with their surface texture can be developed. The overall scanning process, including time required for the post-processing of the data requires less than 20 minutes and is a cost-efficient approach. Moreover, the majority of that time was used in post processing the acquired data which could be potentially reduced through the use of bespoke application software.
This project has provided proof of concept for a new automated, non-invasive and cost efficient registration technique with the potential of providing a quantitative assessment of the articular cartilage integrity during lower limb arthroplasty.