28 April 2006

NEWSLETTER – MARCH 2006

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1. CONFERENCES

The two conferences listed below might be of interest.

1) The *TMJ Bioengineering Conference*, from May 25-27, 2006, in Broomfield (near Denver), Colorado (USA).
   This conference is organised by the TMJ Association (www.tmj.org) and aims to bring together bioengineers, clinicians/TMJ surgeons, scientists, as well as patients to discuss the challenges of TMD.
   For further information, go to the conference webpage: www.tmjconference.org

2) The *5th World Congress on Biomechanics*, is held this year from July 29 -August 4, 2006, in Munich, Germany.
   It is probably one of the largest conferences for Biomechanics, and addresses many different aspects, including modelling (skeletal) muscles and bone.
   For further information, see www.wcb2006.org

2. MASSEY UNIVERSITY, PALMERSTON NORTH (BY SEBASTIAN PAP)

During the last three month, Sebastian finished the mechanical design of the chewing robot (*Figure 1*). Furthermore, he submitted his master thesis with the title "A Chewing Robot Based on Parallel Mechanism – Analysis and Design." at the end of March. The abstract of his thesis is enclosed. He left Massey University and is now on his way home to Germany. In the mid of May (15th- 17th of May 2006), he is going to attend a combined conference (German Conference of Robotics and International Symposium of Robotics) in Munich, Germany. The paper he is going to present is enclosed [*Ed. Please email me (Oliver) or Sebastian directly. I hopefully will be able to improve/move our website such that we can post papers there.*]

“I would like to thank Assoc Prof Andrew Pullan and Dr Oliver Röhrle at the Bioengineering Institute at the University of Auckland, Auckland, New Zealand, Prof Jules Kieser and Ionut Ichim at the School of Dentistry at the University of Otago, Dunedin, New Zealand, and Dr Kylie Foster and Christine Lawrence at the Institute of Food, Nutrition and Human Health at Massey University, Auckland, New Zealand. I really enjoyed working together with you guys. Thanks a lot for showing me all these interesting things in your research fields and for chewing over ideas. All these opportunities broadened my knowledge considerably. I hope to see you guys again.”

Figure 1 Physical model of the chewing robot.

Sebastian Pap’s master thesis is titeled:

A Chewing Robot Based on Parallel Mechanism – Analysis and Design

Abstract

Masticatory efficiency, dependent on number and condition of the teeth, length of time spent in chewing a bolus and the force exerted when chewing, influences an individual with the selection of food and therefore nutritionally diet. A characterisation of the masticatory efficiency could be possible with a chewing robot that simulates human chewing behaviours in a mechanically controllable way (Pap *et al.* 2005; Xu *et al.* 2005).

This thesis describes such a chewing robot, developed from a biological basis in terms of jaw structure and muscles of mastication according to published articles. A six degrees of freedom parallel mechanism is proposed with the mandible as a moving platform, the skull as a fixed

platform, and six actuators representing the main masticatory muscle groups, temporalis, masseter, and lateral pterygoid on the left and right side. Extensive simulations of inverse kinematics (i.e., generating muscular actuations with implementing recorded human trajectories) were conducted in SolidWorks and COSMOS/Motion to validate two mathematical models of the robot and to analyse kinematic properties.

The research showed that selection of appropriate actuation systems, to achieve mandible movement space, velocity, acceleration, and chewing force, was the key challenge in successfully developing a chewing robot. Two custom designed actuation systems, for the six actuators, were developed and built.

In the first approach, the muscle groups were presented as linear actuators, positioned so as to reproduce the resultant lines of action of the human muscles. However, with this design concept the spatial requirements specified from the human masticatory system made the physical building of the model impossible.

The second approach used a crank mechanism based actuator. This concept did not allow a perfectly linear actuator movement that copied the muscle line of action. However, it was possible to fulfil the spatial requirements set by the human system and to allow reproduction of human chewing behaviours in relation to kinematic requirements and chewing force.

The design, manufacture and testing of the entire chewing robot with crank actuators was then carried out. This included the implementation of realistic denture morphology, a mechanical jaw and the framework design for the whole system.

In conclusion, this thesis research has developed successfully a mathematical and a physical robotic model. Future work on the control and sensing of the robot and design of a food retention system are required in order to fully functionalise the device.

2. MASSEY UNIVERSITY (BY PETER XU)

Massey team has recently completed two Master of Engineering in Mechatronics theses in the field of Robotic Chewing. One is titled “A Chewing Robot based on Parallel Mechanism- Design and Analysis” by JS Pap and the other titled “A Robotic Chewing Device for Food Evaluation” by D Lewis.

Massey team, in collaboration with other team, has produced two papers. One is “Designing a Robot Based on Parallel Mechanism to Reproduce Human Chewing Behaviour”, by JS Pap, WL Xu, JE Bronlund, O Roehrle and AJ Pullan, to be presented in the 37th International Symposium on Robotics, Munich, Germany, May 15-17, 2006. This paper presents the updated version of a kinematically focused mathematical model of the robotic jaw system and outlines the design requirements of its actuation system.

The second paper is “Object-Oriented Knowledge Representation and Discovery of Human Chewing Behaviour”, by WL Xu, L Kuhnert, K. Foster, J. Bronlund et al, submitted to an international journal Engineering Applications of Artificial Intelligence, March 2006. This paper deals with a formal description of the chewing behaviour in the context of object-oriented knowledge based systems, which helps constructively understand the mastication process.

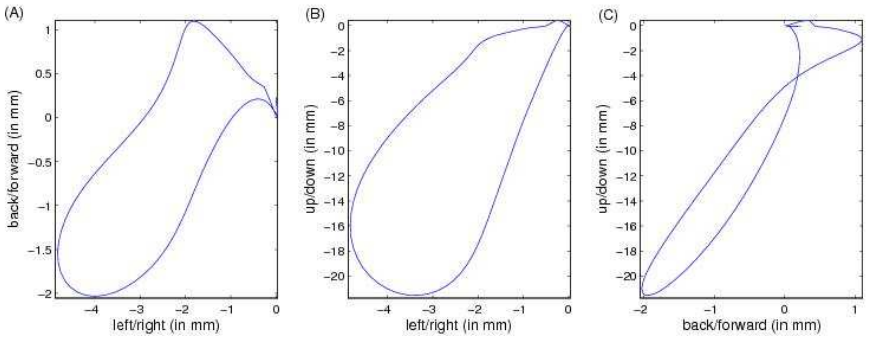
Massey team supported an application for FRST Postdoctoral Fellowship (the fellow is Dr Helen Zhou of Computer Sciences). The proposed research is to develop a Knowledge Based System for Chewing Behaviours. The application was submitted on 6 April.

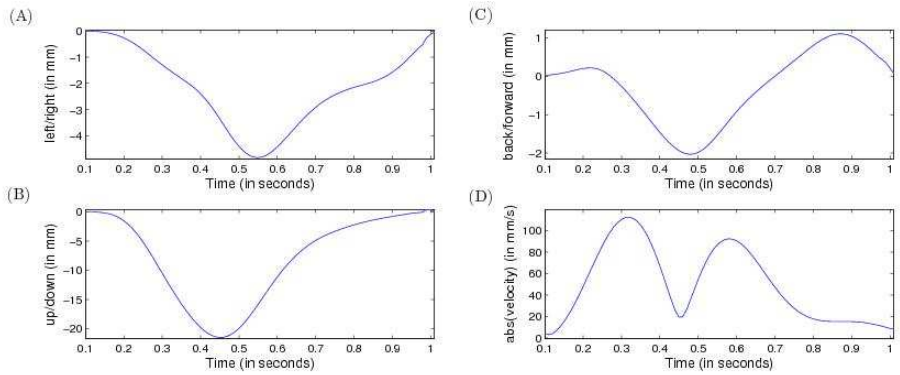
Massey team has built the robot, as shown below (Ed. see also the picture from Sebastian’s contribution), and is working on the motion control via Galil system for different chewing trajectories.

Contributed by Peter Xu

3. THE BIOENGINEERING INSTITUTE, UNIVERSITY OF AUCKLAND (BY OLIVER RÖHRLE)

As reported in the last Newsletter, Oliver and Kylie were carrying out another set of chewing experiments. Upon imposing the recorded data onto our computer model, we realised that the data exhibited quite a bit of (erratic) movement near the TMJ. At first we thought that the positions of the markers at our custom-made appliance were not accurate enough and hence the error would be amplified in regions of smaller movement. As it turned out, our software had a small bug and (against the claims that the data was already smoothed) the recorded data still contained some noise. Applying a simple smoothing technique was enough to get rid of the erratic movements at the TMJ. It turned out that our custom-made appliance and the motion tracking system seems to be a successful combination for recording the movement of the mandible. The figures below show the first chewing cycle of one of the recordings after subtracting the head movement and simply smoothing the data. The first set of figures (A to C) show displacement-displacement curves, while the second set of figures (A to D) depicts the displacement-time (for all three coordinate directions x,y, and z) and the velocity-time curves. The sampling frequency was 100Hz.





In a next step, Oliver is using these data as inputs to a computer simulation in order to obtain muscle forces as output. This process is called inverse dynamics. For that purpose, he imposed the movements shown above on the computer model, enhanced the current muscle geometry by imposing an approximate fibre distribution and a transversely isotropic material description. The goal is to use the finite element method to compute for the displacements, stresses, and strains within the muscles of mastication. From these quantities, one can compute at any arbitrary point within the area of muscle attachment to the bone the direction and magnitude of the muscle force acting on the bone. Currently, the simulations are all set-up and almost ready to go. The hold-up is currently the (mathematical) description of the material properties of skeletal muscles. We have started to include the transversely isotropic material law. Unfortunately, we have not been able to successfully debug the implementation of the material law yet. In general, it also seems that there is not much published on constitutive laws for skeletal muscles that can be used within Finite Element codes (in contrary to the heart muscles).

Besides the computer simulation, we would like to input to the Massey's chewing robot the same trajectories of the mandible. Jonathan is very keen on using this data.

On a side note, John Bronlund and Peter Xu have been approached from a young group of fine arts students at Massey University, Wellington. They are making a documentary about chewing food. They got hold of a (very strange) Japanese guy, called Mr Etani, who has developed a so-called masticator (see http://www.takehitoetani.com/masticator.html). They are going to interview John and Peter about the robot chewing machine and want to have a conversation between Mr. Etani and the Massey chewing robot. It is planned that Oliver will record the movement of the mandible during this conversation and Jonathan will then impose it onto the chewing robot!

Travels

Oliver has received an ISAT Linkage fund from the Royal Society of NZ. This grant funds some research at the Biomechanics Institute at the University of Ulm, Germany (http://www.biomechanics.de/ufb/index_eng.html). For this purpose, Oliver will leave NZ May 25, and return August 8, 2006. On his way to Germany, he will stop at the TMJ conference and, before returning to NZ, he will attend and present some of his current work at the World Congress of Biomechanics.

Andrew Pullan will be on sabbatical from May 18 till mid January 2006, and will also attend the World Congress of Biomechanics.