`14 February 2008

# NEWSLETTER – JANUARY 2008

**Content:**



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## 1. THE BIOMOUTH RESEARCH GROUP WEBSITE (BY OLIVER RÖHRLE)

The Biomouth Research Group's webpage (www.biomouth.org) has been recently updated. On the publication menu item, I have added some more papers by our group, which have been recently submitted or published. For publications that have been already accepted for publication or have already been published, I have created an additional link to the respective pdf files (Thanks Peter for emailing me the pdfs). If we can manage to keep this website up-to-date, I think we have a great repository and show case for our works. To achieve this, I would kindly like to ask you to email me the authors, the title, and the name of journal of the papers which you have submitted or which have been accepted for publication.

I also added a face to the Biomouth group by including some mug shots of people involved with the group. One menu item, which I think we should also keep up to date, is our current and past students which have participated and contributed to various aspects of our work. Please email me names and pictures and I will include them on the website.

As usual, I am always open for suggestions.

## 2. RIDDET CENTRE –CORE (BY JOHN BRONLUND)

Our research teams are now linked to the Riddet Centre of Research Excellence and will receive funding. Andrew Pullan is named as a Principal investigator while John Bronlund and Roger Lentle are Associate Investigators in the new CoRE. The CoRE combines a number of leading and emerging scientists from the University of Auckland, Massey University, the University of Otago, AgResearch and Crop and Food Research. It is led by Professor Paul Moughan and Professor Harjinder Singh.

From the Riddet Centre web site (http://riddetcentre.massey.ac.nz/CoRE)
"New directions in the food industry will leverage off a base of fundamental understanding in biomaterials science, of how food materials assemble and form structures and of how, in turn, these are affected by food processing, ingestion and digestion, ultimately influencing physical and organoleptic characteristics as well as digestive function, nutrient uptake kinetics and satiety. The discovery-based research platforms of the CoRE (Food Materials and Structures, Modelling and Engineering, Gastrointestinal Biology, Innovative Food Solutions) will encapsulate the required underpinning science. The CoRE will address the research theme 'Future Foods — Inspired by Nature' and will foster the development of specialised foods aimed at health, wellness, convenience and pleasure. This multidisciplinary CoRE, networking across organisations, will conduct world-class fundamental and strategic research, will develop human capital and will transfer new knowledge to its stakeholders."

The involvement with the CoRE of interest to the Biomouth group is centred on the "Modelling and Engineering" research platform which Andrew and Professor R Paul Singh from University of Davis, California are jointly coordinating. This platform aims to develop models for different parts of the GI tract. A PhD based at Massey will model bolus formation in the mouth (see advert below). Another PhD supervised by R Paul Singh at Davis will model the flow field in the stomach, how particles affect this and particle breakdown. A Postdoc based at the Bioengineering Institute with Andrew will look at electrical activity in the GI tract.
These projects will each benefit from input from mathematicians named as AI's in the Riddet Core. Further details of the platforms activities will be worked out starting with a Workshop in May, at Massey University, Palmerston North.

## 3. Peter Xu, Massey University, ALbany

The Massey group recently completed a modelling work in EMG generation and adaptation (for rhythmic CPG and its voluntary activities of the masticatory muscles.) The aim of this work was to command the robot in a human way. The method is based on Matsuoka neural oscillator model. The method might also have implication in the biomechanical/mathematical simulation (ie, muscles' activities are generated by the oscillator).

Our manuscript titled "Generation of Rhythmic and Voluntary Patterns of Mastication Using Matsuoka Oscillator" was submitted to Mechatronics. Dr John Sun, a postdoctoral fellow sponsored by China Scholarship Foundation, joined the Massey team late September. He is from Jilin University, Northern China and has a background in agricultural engineering. He is fitting into the team by agreeing to work in the direction of Discrete Element Method (DEM) for Modelling of the Food Mechanics in Chewing. John is contactable at y.sun@massey.ac.nz, and based in Albany.

## 4. Update from the School of Dentistry Biomouth Group, Jules Kieser, University of Otago

I.

The most exciting news for our group is that Ionut has submitted his PhD, based on his excellent and well received papers in the international literature. Sadly, Ionut has now left us, to take up dental practice in Tauranga. However, he still comes down to do some research with his home team of Michael, Neil and Jules. We wish Ionut all the best for the future. Its summer (and what a summer we've had – the hottest and driest in years) and that means that we were able to push our research.


In the picture of our research students we have firstly, Dan Kennedy, who is continuing Bahvia's tongue pressure work for his Clinical Doctorate. Dan has a successor (he completes his study this year), Nittan Raniga, who will look at pressure during mastication. Next is Yikun, who is working on poroelastic modeling of viscoelastic fracture. Tatiana has done a fabulous job of working on the Tuatara skulls and has come up with some very exciting findings. Lastly, Yeen has worked on our Neanderthal mandible, to try and see if the stress fields generated during mastication are the same as in modern humans.

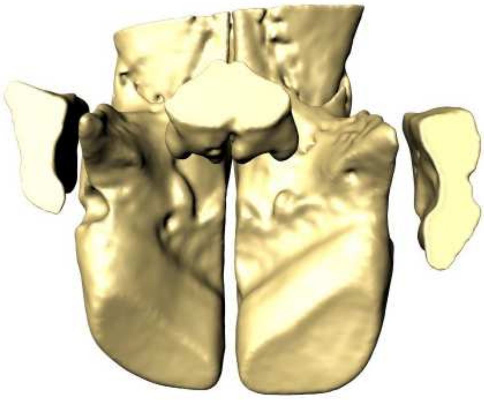
II.

Our intraoral pressure paper has been accepted for DYSPHAGIA: "Measuring intra- oral pressure: adaptation of a dental appliance allows measurement during function" by Jules Kieser, Bhavia Singh, Michael Swain, Ionut Ichim, J Neil Waddell, Daniel Kennedy, and Kylie Foster:

This paper introduces a new way of recording intraoral pressures from a range of locations within the oral cavity. To measure pressure flow dynamics during swallowing, we fitted eight miniature pressure transducers capable of measuring absolute pressures to a chrome-cobalt palatal appliance with a labial bow. Unlike previous devices, our design provides a rigid, custom fitted platform for the simultaneous recording of pressures at eight locations within the oral cavity during function. We placed an anterior pair of gauges to measure lingual and labial contact against the left central incisor tooth, and two pairs of gauges to measure pressure contributions of the lateral tongue margin and cheeks on the canine and first molar teeth. Finally, lingual pressure on the midline of the palate was measured by two gauges, one at the position of the incisive papilla and one on the posterior boundary of the hard palate. We then recorded intra-oral pressures in 5 adult volunteers seated in an upright position and asked to swallow 10 ml of water. Labial pressures on the canine elevated rapidly from a resting level of 10kPa to 33kPa, while pressure profiles from the labial aspects of the incisor and first molar teeth followed a negative pattern, peaking at -12kPa for the incisor, and -15kPa for the molar sensor. Pressure profiles recorded from the palatal aspects of the first molar and the canine appeared to be similar but the former dipped to -13kPa before rising to 9kPa, and the canine pressure rapidly increased to 22kPa before returning to its resting level of 4kPa. The pressure profile of the palatal aspect of the central incisor was strikingly different; at the start of the swallow, pressure dropped precipitously to-20kPa, before slowly rising to 10kPa. It then followed the general pattern of the other two sensors, before peaking again at 10kP, and then returning to a resting level of 4kPa. We also showed that there were significant negative pressured in the mouth during function, and that pressure profiles varied markedly between individuals.

III.

We have taken a big step in the direction of finding out more about mastication in the New Zealand icon, the Sphenodon Tuatara. Together with researchers in University College London and at Victoria University Wellington, we have established a research group that will now analyse mastication in models and in real specimens of this rare animal. The figure above comes from Ionut and Jules who are scanning and modelling Sphenodon jaws, to try and evaluate toothwear patterns.

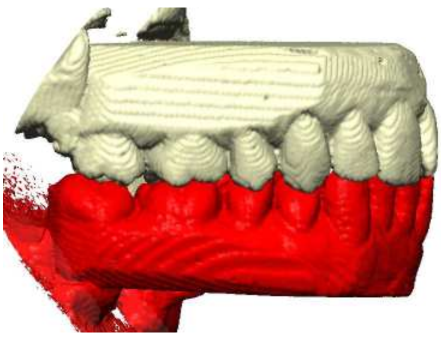


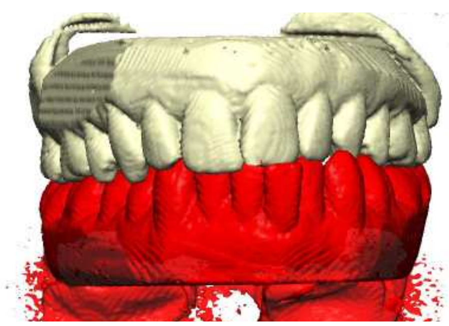
5. HAPPENINGS AT THE DEPARTMENT OF ENGINEERING SCIENCE AND THE BIOENGINEERING INSTITUTE, THE UNIVERSITY OF AUCKLAND

In the past year, Andrew and Oliver had two $4^{th}$ year student projects related to the Biomouth research:

One project entitled “Describing Mandibular Movement during Mastication” was carried out by Harry Saini. He used image analysis techniques to visually represent and analyse patient-specific chewing trajectories with six degrees of freedom. For this purpose, we used the μCT at the ABI to create high-resolution images from imprints that have been cast from Oliver’s teeth. The idea was to create separate models of the lower and upper teeth, to bring them into occlusion, and to apply Oliver’s previously recorded chewing trajectories. To achieve occlusion in the model, the casts of the upper and lower teeth have been brought into occlusion and fixed with a wire. The wire was then snapped and the upper and lower casts (including the wires) were scanned separately. In a post-processing step, the two geometric models of the lower and upper teeth (obtained by image-analysis techniques) have been brought into occlusion by aligning the wires. Further, a Faro-arm measuring device has been used to register specific markers on the chewing appliance to the geometrical model. (See previous newsletters for a more detailed description of how the appliance was designed and used to track the motion of the mandible during chewing.) Then, the chewing trajectories have been imposed on the model and the movement of the teeth during chewing has been analysed.

Harry has also received a summer studentship from the Auckland Bioengineering Institute and continues to work on new ideas related to his $4^{th}$ year project. First, he improved the geometrical models of the upper and lower teeth and their occlusion (see Figures below). He is currently exploiting an idea to see if it is possible to reconstruct an optimal cusp shape based on the anatomical geometry of the surrounding teeth.





The 4th year project of the second student, Nirukta Patri, was entitled the "Analysis of Human Chewing Dynamics". She performed a sensitivity analysis based on our previous work "Three-dimensional finite element analysis of muscle forces during mastication" (Journal of Biomechanics). She analysed the computed masseter muscle force using different constitutive parameter.

## 7. MASSEY CHEWING – AN UPDATE FROM JOHN BRONLUND

**Progress**

The Massey research team has continued to work on a number of fronts.

Some of you will know that Kylie Foster and Husband Mike have added a beautiful daughter (Amanda) to their family. Congratulations to them both. Maybe Kylies work might shift to chewing in infants now.

Our work on *understanding human chewing* and its interactions with foods and food texture is continuing. Christine Flynn (nee Lawrence – Yep now married) is writing up her PhD thesis. She has started work with Sanatarium in January but has managed to integrate her thesis work into her busy life. She hopes to submit in June. Scott Hutchings has made real progress in sorting out articulograph and EMG measurement methodology. Together with Jonathan Torrance and Peter we are looking to develop analysis methods to provide useful data to characterise chewing trajectories. Scott is beginning to finalise experimental plans to investigate the potential to influence chewing trajectory by inclusion of different secondary food components within different baked product food matrices.

*Robotic simulation* work is also moving on well. Jonathan Torrance is working towards completing his thesis on control of the 6dof chewing robot by mid year. Richard Sun has completed the first 12 months of his PhD and will continue to focus on development of the 2D robotic chewing device developed in collaboration with Crop and Food Research. This device has been modified to allow realistic application of force to foods and measurement of 3D force measurement under the molar array. The device has been characterised in terms of the resulting particle size distribution and how sensitive this is to the various settings that can be made to the system. Richard is now working on devices to retain the food on the molar array during repeated chewing cycles.

Peter has continued to extend the work he has started on advanced control of the robotic chewing machines, now including CPG type neural control concepts. The initial stages of this work is written up in a paper recently submitted to Mechatronics (see abstract below).

**New projects – opportunities**

*Future Foods – NERF project (Riddet Centre – Massey University).*

This project is focused on understanding how nano-stuctures (mostly natural ones) affect nutrient release in the digestive tract. It has objectives involving characterising nano and micro structures, what happens to them in the mouth and in the stomach.

We have new funding for two PhD's in this project centred on the mouth. One will focus on the movements of the tongue, application of shear to foods and incorporation of saliva and amylases into the food matrix. The PhD will overlap with the work on intra oral pressures in the mouth at Otago and offers an ideal opportunity to strengthen this collaboration. The second project will focus on developing physical models of the mouth and the pharanx. It will offer opportunities to understand the bolus properties required for safe swallowing. We are working up details of these projects at present.

*Riddet CORE*

Jim Jones and John Bronlund will supervise a new PhD student funded under the Riddet CORE. The project will work in collaboration with other organisations in the CORE and will seek to develop a modelling framework to integrate the various dynamic processes occurring during chewing. Size reduction, mixing, dissolution, loss to other parts of the mouth, moisture absorption by the developing bolus and component particles all affect cohesion of the bolus being formed. Each of these processes has been investigated in other applications (eg granulation). In this project we aim to combine them together. An advert is attached to this newsletter.

*Current PGS&T round*

Kylie Foster and John Bronlund have been assisting in development of a new NERF bid on linking sensory evaluation to mastication and food structure. This proposal is led by Crop and Food Research and included collaboration with Auckland University, Dept of Food Science and Hort Research. The application is about to be submitted to the Foundation in the second and final stage of the process. If successful it will occupy a large component of Kylies time and fund two PhD's investigating food particle deformation and fracture and its interactions with molar trajectories. It may build on some of the preliminary work on fracture modelling that Ionut started in his work.

## Outputs

The Massey Team has produced a few paper outputs that some might be interested in.

In press:

**Design of a Biologically Inspired Parallel Robot for Foods Chewing**

Xu, W. L. Pap, J.-S. Bronlund, J.

IEEE Transactions on Industrial Electronics, Feb. 2008, Volume: 55, Issue: 2, page(s): 832-841

**Abstract -** To quantitatively assess food texture changes and/or masticatory efficiency during chewing, the jaw movements and chewing/biting forces must be measured. For this purpose a robotic solution has been proposed to reproduce human chewing behaviour. The chewing robot of parallel mechanism is based on the biological finding that the mandible is pivoted at the tempomandibular joints (TMJ) and driven by groups of muscles for opening and closing of the mouth. This paper reviews the biomechanics of the mastication system, defines the kinematical mechanism of the chewing robot and describes the design of the actuation systems. With a linear actuator for a muscle group of mastication, its spatial placement between the mandible or moving plate and the maxilla, or ground plate follows the line of action and attachment sites of the muscle. The design requirements for each actuation system are specified mainly as the actuation range, velocity and acceleration, and the actuation force, which are determined by inverse kinematics analysis via simulation software and the jaw force analysis via Pythagorean Theorem, respectively. A design of the physical linear actuation which is made up of a rotary motor, a gear reduction train and a lead-screw is presented while the challenges are discussed for building the entire chewing robot.

**Kinematics and Experiments of a Life-sized Masticatory Robot for Characterising Food Texture**

Xu, P., Torrance J.,Potgieter J., Bronlund J. and Pap J-S

Accepted by Transactions on Industrial Electronics.TIE-00752-2007.R2 on Jan 08

**Abstract -** A life-sized masticatory robot of 6RSS parallel mechanism is dealt with in the paper, which is intended to chew foods in a human way while the food properties are evaluated. The robotic mechanism is proposed following the biomechanical findings of the human masticatory system, and its kinematic parameters are defined in skull and mandibular coordinate systems. For a given mandibular trajectory to be tracked, the closed form solution to inverse kinematics of the robot is found for joint actuations while differential kinematics is derived in Jacobian. Major features of the built robot including the motion control system are presented. Experimental results for free chewing, soft-food chewing and hard-food chewing are given where the foods are simulated by foam and hard objects. Joint actuations and driving torques required are compared for the chewing of different foods.

Paper Submitted to MECHATRONICS, October 2007

**Generation of Rhythmic and Voluntary Patterns of Mastication Using Matsuoka Oscillator**

W.L. Xu, F. Fang, J. Bronlund and J. Potgieter

**Abstract -** We intend to apply Matsuoka neural oscillator into humanoid chewing robots to generate rhythmic actuation of CPG and adapt it for voluntary actuation due to sensory feedback. In this paper a single Matsuoka oscillator of two neurons is used for two phase-locked muscles (e.g. masseter and digastric muscles) or for a single robotic joint. To help design and tune the oscillator we have developed three graphical user interfaces (GUI) with aid of which the simulation, parameters' influence and adaptation of the oscillator can be analysed and for specific pattern of muscle activities the oscillator can be selected. Discussions are made in relation to the experimentally confirmed EMG of muscle activities for various foods. A case study involving a jaw, driven by a couple of opening and closing muscles that are commanded by motoneurons is presented. The force of the muscles is described in nonlinear Hill model while the motoneuron for muscle activities is modelled in the oscillator. Simulations are performed to show the oscillator's ability in generating and adapting its rhythmic outputs with respect to the chewing without food (i.e, EMG only for rhythmic muscle activities), with foods (i.e., EMG for rhythmic and additional muscle activities) and with crushable foods (to see how quickly the oscillator to reduce its force commands in order not to damage the teeth). Our work is also meaningful for brain-based control of assistive or rehabilitative devices and EMG-driven neuromusculoskeletal models.

Paper Submitted to - Archives of Oral Biology, December 2007

**Multivariate analysis of food particle size distributions after human mastication.**

C.S. Flynn, R.G. Lentle, K.D. Foster, J.E. Bronlund, J. R. Jones, M. Morgenstern

**Abstract -** Mastication to the point of swallowing was studied by collecting particle size distributions (PSDs) for five foods with differing characteristics using ten male subjects and two portion sizes. Two PSDs were obtained by wet sieving from each chewing trial for the expectorated bolus and the debris subsequently rinsed from the mouth. The data set is large and many analyses can be performed but here we limit ourselves to exploring the PSD differences between the bolus and debris as a function of food type and portion size. Evaluation was by multivariate analysis and principal component analysis. Subject variation is included but not studied. Results show significant PSD differences between the bolus and the debris which suggests a two compartment system where particles are comminuted in at least one compartment within the oral cavity.

Two papers will be presented at ICEF10 (International Congress of Engineering in Food) – Vina del Mar – Chile April 19-22 2008.

**A 2D chewing simulator - mechanism and results**
Bronlund J.E., Sun C., Lewis D., Xu W.L. and Morgenstern M.

**Robotic simulation of 3D human chewing trajectories**
Bronlund J.E., Torrance J, and Xu W.L