11 September 2008

NEWSLETTER – SEPTEMBER 2008

Content:

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1. SOME CHANGES TO THE BIOMOUTH RESEARCH GROUP (BY OLIVER RÖHRLE)

I have recently accepted a Junior-professorship for ‘Continuum Biomechanics and Mechanobiology’ at the newly formed excellence cluster for simulation technologies (‘SimTech’) at the University of Stuttgart. For that purpose, I will be moving to Germany in mid November – to be precise on November 16, 2008. As part of my new position, I probably will focus a little bit more on skeletal muscle research than on jaw and teeth mechanics, but I hope to continue some of my current research efforts in this field and, of course, hopefully maintain my good linkages to New Zealand and the Biomouth Research Group. I think the Biomouth Research Group has gained quite a bit of momentum over the last years and formed a very nice and strong group of people from various disciplines.

With me leaving New Zealand and the current NERF funding, which initiated most of our collaborations, coming soon to an end, there will be some changes to the future. First of all, I would like to thank Kylie Foster for kindly agreeing to edit and continue the tradition of the Biomouth newsletter. I personally think that the newsletter is very important to maintain and build on our previous and current efforts. Starting from the next one, she will be asking you for contributions, will be editing the newsletter, and then will be emailing it out to us all. Many thanks Kylie.

With the end of our current research grant contract, there will be no more formal linkages among most groups. However, we all agreed at the last Biomouth Symposium that the Biomouth Research Group should continue as a loose research network that fosters new cross discipline research and takes advantage from the strong and diverse background and expertise within the group. We also agreed that we will not try to apply for new research grants as a whole group, but that we rather try to pursue individual initiatives that require the input/collaboration of some of the other group members. We also decided that we would like to continue to hold (annual) research meetings and raised the suggestion to combine our meetings with the other ones like the NZIFST or the Riddet Centre (to which some of the members have also very close ties).

Our 2nd Biomouth Symposium in Rotorua, NZ on June 23/24 has been a great success. I have included our program schedule and all the abstracts as an item to this newsletter (or http://www.biomouth.org/assets/files/pdf/Web-ProceedingsBiomouthSymposium2008.pdf). I think the pre-symposium meeting and the traditional South African BBQ has been a great success and help to form an either stronger bond between all the participants. It was also great to see all the students and interns presenting their great work from the last year(s). To revisit some of the good and memorable moments of this meeting, I collected and published some of the pictures on the Bioumouth website (http://www.biomouth.org/index.php?id=69). Enjoy.

2. ArtiSynth and Satellite Symposium of the International Association of Dental Research General Session in Toronto, Canada (By Christopher Peck)

On July 1st 2008, a satellite symposium of the International Association of Dental Research General Session in Toronto, Canada was held to honour three giants in orofacial neuroscience. One giant was Professor Alan Hannam, who hails originally from the University of Adelaide and has spent much of his research career focussed on muscle physiology and mathematical modeling of the jaw. Professors' Barry Sessle and James Lund, originally from The University of Sydney and Adelaide respectively are also extraordinary neuroscientists who were honoured in the tribute. Professor Hannam was until recently Professor in Oral Biology and Oral Health Sciences at the Faculty of Dentistry, University of British Columbia. He is now Emeritus Professor and continues enthusiastically with teaching and modeling research. He is working closely with an interdisciplinary group on jaw, tongue, pharynx and larynx modeling, and more information on this can be found at artisynth.org. I was honoured to coordinate the tribute to Alan and 7 papers were presented which will be summarized in an upcoming issue of the Journal of Orofacial Pain.

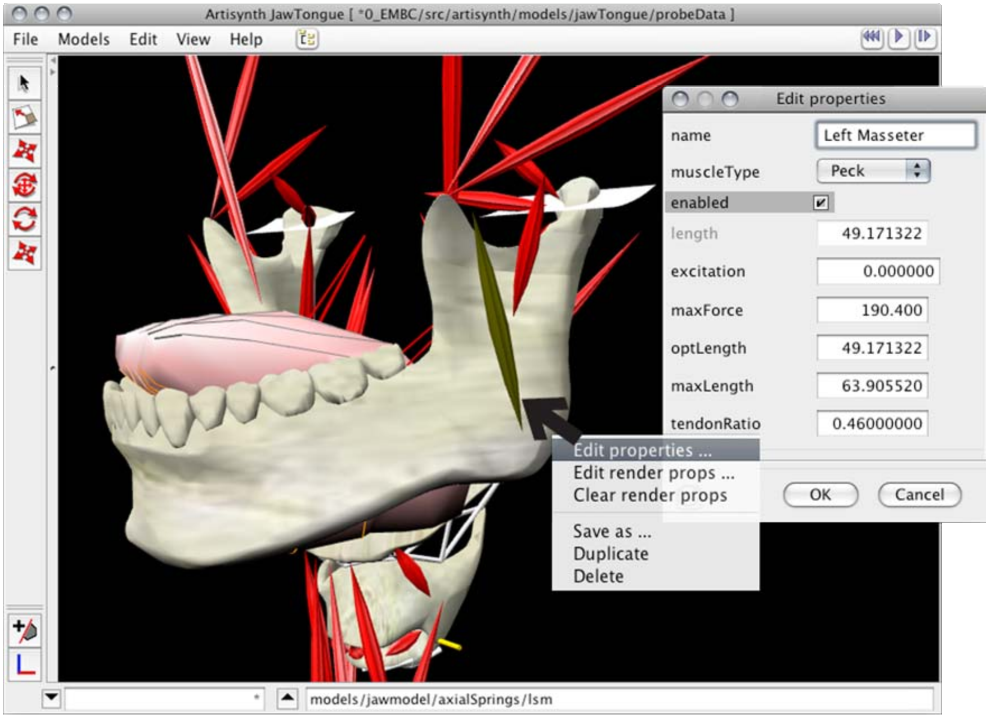

Figure 1: The dynamic Jaw-Tongue-Hyoid model in ArtiSynth with a property-editing panel for the selected jaw muscle. (Figure is from a artsynth model, courtesy of Ian Stavness)

3. New Research Programme gets the go-ahead (by Marco Morgenstern)

The Foundation for Research, Science and Technology (FRST) has agreed to fund a new programme to study the relationships between food structure and sensory perception. In a collaborative effort between Crop & Food Research, HortResearch, Massey University and Auckland University, researchers will study the way that food structure interacts with sensory perception during mastication. The overall aim of the programme is to develop fundamental knowledge that will allow solid food structures to be designed and manipulated in order to enhance their sensory appeal.

There are three integrated components to the research: designing mono-attribute structures and quantifying their properties; measuring structure deformation and breakdown in the mouth; and determining the link between the two. Building food structures that vary a single sensory attribute is a major challenge and will be done by using simple structures made from food or even non-food ingredients. A new approach in sensory evaluation will be used that tries to describe sensory properties in terms that are closely related to engineering concepts, rather than with traditional consumer-driven semantics.

The new programme adds a sensory component to mastication research in the Biomouth Research group through sensory scientists Roger Harker of HortResearch and Virginia Corrigan of Crop & Food Research. The research builds on the mastication studies of Kylie Foster, John Bronlund and Marco Morgenstern and will use the 2D robotic chewing device that was presented at the Rotorua symposium. Bryony James of Auckland University will focus on enhancing the engineering approach to food structure characterisation.

A five-year contract is currently under negotiation with FRST and the work is expected to start in October 2008.

Marco Morgenstern
Crop & Food Research

4. Short update on happenings at the Bioengineering Institute and publications from The Biomouth Research Group (by Oliver Röhrle)

Harry Saini has left us to study for a year at the University of California at Davis in the US. We all whish him the very best for his overseas experience! Before he left, he managed to submit his work as a paper entitled ‘Automatically Generating Subject-Specific Functional Tooth Surfaces Using Virtual Mastication’ to the Annals of Biomedical Engineering.

Yikun Wang is continuing his work on tongue modelling. He has made great progress towards the challenging problem of implementing in CMISS his new ideas on modelling interlacing muscle fibres. He is currently trying to debug and validate his additions to the code.

The paper ‘Using a motion capture system to record dynamic articulation for application in CAD/CAM software’ by O. Röhrle, J.N. Waddell, K. Foster, H. Saini, and A. Pullan has been, according to the reviewers comments, revised and resubmitted to the Journal of Prosthodontics. We hope to hear some positive news from the editors of the journal soon!

Furthermore, the paper ‘Review of the Human Masticatory System and Masticatory Robotics’ by P. Xu’s, J. Bronlund, j. Potgieter, K. Foster, O. Röhrle, A. Pullan, and J. Kieser for the journal of Mechanism and Machine Theory is now in press and can be downloaded from http://dx.doi.org/10.1016/j.mechmachtheory.2008.06.003.

Abstract ‘Review of the human masticatory system and masticatory robotics’:

A masticatory robot refers to a robot that can perform at least some defined human masticatory functions. This paper briefly reviews the masticatory system, masticatory measurements and computational models of mastication that are relevant to masticatory robotics. Also critically reviewed is the state of the art of the robotics research in engineering of the jaw system. The masticatory system has two rigid components: a fixed maxillary (upper) jaw and a mobile mandibular (lower) jaw, which are joined by two temporomandibular joints (TMJ). Unique features of the TMJ are described. The role of muscles of mastication is explained with regard to their role in rhythmic opening and closing of the mandible in three-dimensional space. Because the breakdown of food is performed directly by the teeth; the functionalities of the incisor, pre-molar and rear molar are presented. Two computational models of the masticatory system are presented in which Hill-type muscle models are used. We also describe masticatory robots developed for dental training, jaw simulation, food texture and breakdown analysis, and speech therapy with regard to muscle modelling, TMJ models, masticatory biomechanics and controls of actuation. Finally, we discuss the major accomplishments and challenges in masticatory modelling and robotics; and we compare a number of such robots in the light of relevant biomechanical aspects of the mastication system.

Abstract ‘Automatically Generating Subject-Specific Functional Tooth Surfaces Using Virtual Mastication’:

The functionality of dental restorations depends on the ability to identify patient-specific functional and occlusal tooth surfaces. This paper demonstrates how the combination of patient-specific chewing movements (recorded with a VICON MX motion capture system) and high-resolution geometric models (reconstructed from μCT images) can be utilised in computer aided design and manufacture (CAD/CAM) processes to automatically reconstruct functional and occlusal tooth surfaces. The algorithm investigated in this paper is based on the idea that functional tooth surfaces can be reconstructed by removing collisions occurring between a generic maxillary tooth/teeth and the mandibular teeth during mastication. Moreover, by comparing the results of the reconstruction process with the actual tooth morphology, one obtains a natural error measure to quantify the quality of the reconstructed functional tooth surfaces as well as a tool to measure the accuracy of recorded chewing trajectories. Based on one subject's right second maxillary molar, a thorough error analysis of this virtual model, the so-called virtual masticator, has been carried out. The results show that the errors within the occlusal and functional regions of the the right second maxillary molar are small (-90µm to 200 µm, if compared to the actual tooth) and remain constant after 3 chewing cycles. Based on the error analysis of the virtual masticator presented herein, it is believed that the most significant source of error is the resolution of the motion capture system. However, the overall accuracy of the virtual masticator is high enough to suggest that the use of this algorithm in the design process of subject-specific tooth replacements is feasible.

5. Program and Abstracts from the 2nd Biomouth Symposium, June 23/24 2008.

See following pages:

THE NEW ZEALAND INSTITUTE OF FOOD SCIENCE & TECHNOLOGY INC

NZIFST ANNUAL CONFERENCE 2008
24-26 JUNE
ROTORUA

2ND BIOMOUTH SYMPOSIUM

Scientific sessions:

Tuesday June 24, 2008: 9.30 am - 5.00 pm

Energy Events Centre, Rotorua, New Zealand.

Conference BBQ:

Monday June 23, 2008: 6pm onwards

313 Fenton Lodge Holiday House, Rotorua, New Zealand

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Monday, June 23, 2008

From 6pm	Conference BBQ and pre-meeting get-together. All are welcome. Address: 313 Fenton Street, Rotorua, New Zealand. For further details, please see last page.

Tuesday, June 24, 2008: **at the Energy Event Centre Rotorua**
First Sovereign Trust Room (Upstairs)

8:00 – 9:30	Registration – Exhibition Hall (at the NZIFST Conference Desk)
9:30 – 9:45	*Opening and Welcome* – **Oliver Röhrle**
9:45 – 10:30	**Dale Every**, *New Zealand Institute for Crop and Food Research Ltd*, "HOW WE CHEW OUR FOOD AND EVOLUTION OF TEETH SHARPENING MECHANISM - THEGOSIS"
10:30 – 11:00	*Morning tea*
11:00 – 11:30	**Jules Kieser**, *University of Otago*, "PATTERNS OF PRESSURE CHANGE DURING SALIVA SWALLOWING"
11:30 – 12:00	**Mikel Rodrigo,** *Massey University, Palmerston North,* **"CONSTRUCTION OF A MODEL SWALLOW - A PHARYNGEAL RHEOMETER"**
12:00-12:30	**Yikun Wang,** *Auckland Bioengineering Institute,* **"MODELLING OF INTERLACING MUSCLE FIBRES WITHIN THE TONGUE"**
12:30 – 13:30	Lunch
13:30 – 14:00	**Scott Hutchings,** *Massey University, Albany Campus,* **"NATURAL BITE SIZE: DIFFERENCES BETWEEN FOODS AND APPLICATIONS FOR NEW SERVING METHODS IN MASTICATION STUDIES"**
14:00 – 14:30	Yujing Sun, ***Massey University, Albany Campus,*** **"**SIMULATION OF FOOD MASTICATION BASED ON DISCRETE ELEMENT METHOD"
14:30 – 15:00	Harry Saini,***, Auckland Bioengineering Institute,*** **"AUTOMATICALLY GENERATING SUBJECT-SPECIFIC FUNCTIONAL TOOTH SURFACES USING VIRTUAL MASTICATION"**
15:00 – 15:30	***Afternoon Tea***
15:30 – 16:00	Richard Sun***, Massey University, Albany Campus, "A 6 BAR LINKAGE CHEWING MACHINE - NOW AND WHAT'S NEXT"***
16:00 – 16:30	**Otmar Nitsche**, Massey University, Albany Campus, „CONTROLLING OF AN ARTIFICIAL CHEWING ROBOT WITH THE MATSUOKA NEURON MODEL"
16:30 – 17:00	Oliver Röhrle**, Auckland Bioengineering Institute, "MODELLING MUSCLES OF MASTICATION/SKELETAL MUSCLES" and "OUTLOOK AND FUTURE CHALLENGES OF THE BIOMOUTH RESEARCH GROUP – SOME RESULTS AND INSIGHTS FROM THIS WORKSHOP"**

Tuesday, June 24, 2008 9:30-10:30:

HOW WE CHEW OUR FOOD AND EVOLUTION OF TEETH SHARPENING MECHANISM – THEGOSIS

Dale Every

NZ Institute for Crop & Food Research Ltd, Private Bag 4704, Christchurch, New Zealand

EveryD@crop.cri.nz

When we chew, our teeth chop, split, break, crack, crush, squeeze, flake and grind the food and these aspects of chewing are well understood. However, it is not well understood that cheek teeth can effectively comminute food by a cutting action as well. Different foods elicit different chewing actions. Tough, plastic or hard-elastic foods elicit a greater lateral action of the teeth in the final occlusal phase of chewing, and this allows for relatively sharp blade systems on cheek teeth to cut the food. The dynamics of this cutting action are difficult to understand because of the complicated spacial relationships of cusps, valleys and enamel cutting edges on cheek teeth. I have found a remarkable analogy between the chewing and wheat roller-milling mechanisms, which I describe in this talk in the hope that it will aid understanding of the principles of chewing. I will also present evidence for the evolution of a teeth-sharpening mechanism (thegosis) in hominids gained from research in Ethiopia (Oct 2008) on fossil teeth of *Australopithecus afarensis* (3 million years ago), *Ardipithecus ramadus* (4.5 mya) and *Ardipithecus kadaba* (5.2 mya), one of our earliest known hominid ancestors.

Tuesday, June 24, 2008, 11:00-11:30:

PATTERNS OF PRESSURE CHANGE DURING SALIVA SWALLOWING

Daniel Kennedy[1], Jules Kieser[1], Michael Swain[2], Christopher Bolter[3], Bhavia Singh[1], and J Neil Waddell[2]*

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[2] Department of Oral Rehabilitation, Faculty of Dentistry, University of Otago, Dunedin, New Zealand
[3] Department of Physiology, School of Medical Sciences, University of Otago, Dunedin, New Zealand

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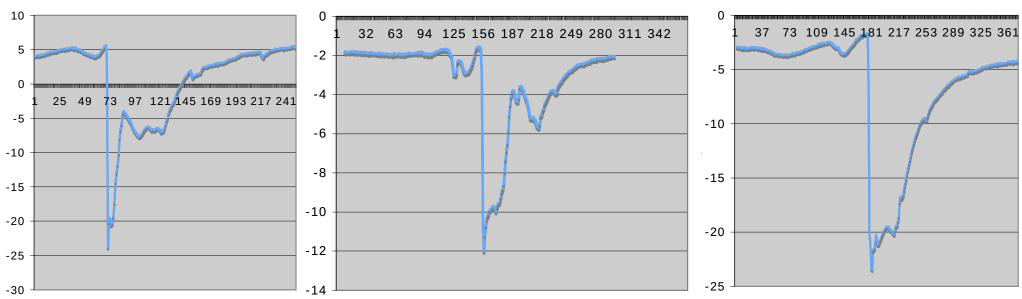
Despite considerable literature on the generation of intra-oral pressures during the oral phase of swallowing, there are few papers that have focused their attention on the gathering of simultaneous data from different sites within the mouth. We recently introduced a rigid, custom fitted platform for the simultaneous recording of absolute pressure within the oral cavity during function. This device was able to deliver continuous readings of both positive and negative pressures from eight sites within the oral cavity. We test three hypotheses; first, that there are defined individual patterns of pressure change within the mouth during liquid swallowing; secondly, that there are significant negative pressures generated at defined moments during normal swallowing; and thirdly, that liquid swallowing is governed by the interplay of pressures generated in an antero-posterior direction in the mouth. Four miniature pressure transducers with stainless steel diaphragms were used for absolute pressure measurement (0 – 420 kPa) in both positive and negative ranges. These were located as follows: one buccally on a labial bow, at the point of maximum convexity of the central incisor. One on the palatal surface of the same tooth and the remaining two in the midline of the palate, one at level of the distal of the first premolar and the second slightly anterior to the junction of the hard and soft palate.



Our graphs represent pressures in kP pooled for a single individual. It is clear that there is a definite patterning to pressure changes recorded in the midline, that there are significant negative pressures generated and finally, that there is a sequence of changes from anterior towards the pharynx.

Tuesday, June 24, 2008, 11:00-11:30:

CONSTRUCTION OF A MODEL SWALLOW – A PHARYNGEAL RHEOMETER

M. Rodrigo[1], R. Lentle[2], and J.E. Bronlund[1]

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It is widely postulated that the end point of masticatory processing is in the production of a food bolus that is safe to swallow. Physical characterisation of a food bolus at the point of swallow is difficult due to its dynamic nature. Food particles continue to absorb moisture, solute dissolution can continue, sample size can often limit the validity of standard rheological techniques and it can be difficult to relate the results to the actual conditions during swallowing. To circumvent these problems, we propose to design and construct a physical model pharynx which will be used to evaluate the flow properties of a food bolus. We present a conceptual description of the mechanisms of food bolus swallowing and how a specification for the model system was developed. Some preliminary designs for the model swallow system will also be presented.

Tuesday, June 24, 2008, 12:00-12:30

MODELLING OF INTERLACING MUSCLE FIBRES WITHIN THE TONGUE

Y. Wang, A.J. Pullan, and O. Röhrle

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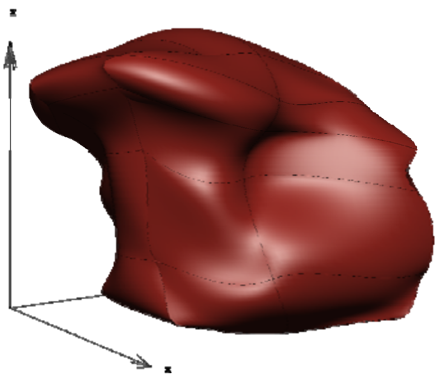
The biomechanical behaviour of the tongue is relatively poorly understood. This is mainly due to its complicated structure, shape, and its limited visibility. Most of the computational models of the tongue were developed with the aim to investigate the tongue's movement and its change of shape during speaking. However, none of the existing models studies the muscle activity patterns i.e., muscle activity patterns during specific movement like swallowing. This is mainly due to the complicated structure of interlacing muscle groups within the tongue. My talk will give an introduction on how we plan to develop an anatomically-realistic tongue model which is capable of investigating such movements.

The current implementation of CMISS, the modelling software developed by the Auckland Bioengineering Institute, is only set up to define one set of fibre distribution per computational element. In classical continuum mechanics, there exist a vast number of applications that deal with interlacing structures i.e., composite materials such as the steel-reinforced rubber of tyres. To some extend, biological soft tissues can be considered as a fibre-reinforced hyperelastic material. For example, the layers of the arterial wall are composed mainly of an isotropic matrix and two families of fibres. Hence, guided by such work and the more classical work on composite materials, we attempt to modify the strain-energy function of an existing skeletal muscle model to mimic the behaviour of interlacing fibres.



Tuesday, June 24, 2008, 13:30-14:00:

NATURAL BITE SIZE: DIFFERENCES BETWEEN FOODS AND APPLICATIONS FOR NEW SERVING METHODS IN MASTICATION STUDIES

S. Hutchings[1], K. Foster[1], J. Bronlund[2], R. Lentle[1], J. Jones[3], M. Morgenstern[4]

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[2] School of Engineering and Advanced Technology, Massey University
[3] School of Engineering and Advanced Technology, Massey University
[4] NZ Institute for Crop & Food Research Ltd, Christchurch, New Zealand

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Almost all mastication studies serve constant mass or constant volume samples to subjects. However, studies which have compared the natural bite weight of foods show that differences exist depending on the food. 45 subjects (21 males and 24 females) took part in a study taking natural bites of 6 different manufactured food bars. Bite weight was measured, and volume and length of each bite was estimated from density and cross sectional area. The number of chews and chewing time from each bite was also recorded. Results show that natural bite weight, volume, length, and chew work were significantly different between bars. These results suggest that serving samples of constant weight, volume, or shape in studies which are comparing foods or food properties does not accurately reflect the entire eating process. Therefore, the quantity served should be varied depending on the type of food, and should be determined by assessing natural bite sizes of the food of interest before the study begins. An alternative option is to allow subjects to take natural bites for mastication studies. Results also suggest bite size might be linked to food properties (shape and density in particular). This is an area requiring further research.

Tuesday, June 24, 2008, 14:00-14:30:

SIMULATION OF FOOD MASTICATION BASED ON DISCRETE ELEMENT METHOD

Y. Sun[1,2], *W.L. Xu*[2]

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Information on mastication and food sensory property is usually collected by recording people's ingesting and chewing action using electromyography, fluorography, cinephotography, ultrasonography and videofluorography, and so on. The process of human food mastication and swallowing is investigated by discrete, or distinct, element method (DEM) in this paper. DEM is a kind of numerical analysis and simulation method for particle material motion and had been applied not only to soil or rock mechanics problems but also to applied mechanics, such as powder mechanics and dynamics of particulate media and engineering. The fundamental concepts, algorithms and some examples of DEM application are presented. Two initial models of human chewing and swallowing are constructed and relevant simulations are conducted by PFC2D 3.1 software. The chewing of rectangle food, round food, round food with a hole and the food swallowing are simulated. Changes in food reduction and jaw motion with respect to food mechanical properties and oral cavity state are observed during simulations. The movement and interaction of food particles, contact stress and strain among food particles, contact forces between the particles and teeth are recorded and analysed. Results from simulations can help understand better masticatory performance and food product development.

Keywords: Mastication, DEM, food mastication simulation, food property, food modelling

Tuesday, June 24, 2008, 14:30-15:00:

AUTOMATICALLY GENERATING SUBJECT-SPECIFIC FUNCTIONAL TOOTH SURFACES USING VIRTUAL MASTICATION

H. Saini, A.J. Pullan, and O. Röhrle

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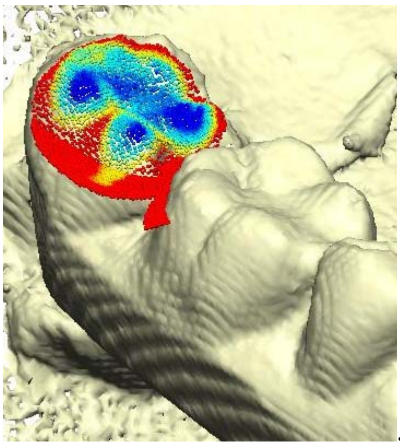
The main aim of this work was to use shape optimisation to recreate cusp geometry, based on the shape and chewing movements of the opposing teeth. To achieve this, we first generate "voxel" models of the upper and lower teeth of interest (we chose the right, upper and lower, second molars). We then generate the "generic geometry"; for simplicity our generic geometry or stock was based on the upper tooth and was generated by simply extruding the upper tooth surface by a predetermined distance. Finally, the stock was optimised according to lower tooth chewing trajectories – if the lower tooth voxels occupied the same spatial coordinates as the stock voxels, at any given time during the chewing trajectories, the stock voxels were removed. The resultant optimised stock shape is then compared to the original upper tooth.

The proposed methodology also reveals functional tooth surfaces in regards to the given chewing trajectories. These functional surfaces could be used as geometric constraints to aid design of dental implants such as crowns and bridges.

.

Tuesday, June 23, 2008, 15:30 – 16:00:

A 6 BAR LINKAGE CHEWING MACHINE – NOW AND WHAT NEXT

R. Sun[1], W.L. Xu [1], L. Huang[1], M. Morgenstern,[2] and J.E. Bronlund[1]

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A 6 – bar linkage mechanism chewing machine has been developed for sample preparation for in vitro nutritional analysis and real-time force texture measurement (Lewis et al 2008). The device has been improved through inclusion of a static food retention system, redesign of a passive force application system and inclusion of a 3D force sensor under the occlusal surfaces. The reproducibility of the chewing outcomes achieved with the device was assessed along with the sensitivity of the resulting particle size distribution to changes in device parameters. These results along with planned future work on the device will be presented, including aspects of active manipulation of the food between chewing cycles and investigation of potential force control strategies to develop the device into an accurate physical model of human mastication.

Tuesday, June 24, 2008, 16:00 – 16:30:

CONTROLLING OF AN ARTIFICIAL CHEWING ROBOT WITH THE MATSUOKA NEURON MODEL

Otmar Nitsche[1], *W. L. Xu*[2], *Prof. Dr. Kai Müller*[1]

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[2] School of Engineering and Technology, Massey University, Auckland, New Zealand

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The goal of this half-year project is to show that it is possible to control a simplified chewing robot by the Matsuoka Neuron model. Since the assignment is not finished yet, the presentation will only show the current work progress.

The device will consist of two pneumatic muscles, one for opening and one for closing the mouth. Each of the actuators will be operated by proportional valves to allow a precise movement. The feedback signal will be composed of a motion signal, gathered by an optical incremental encoder, and a force signal, gathered by a load cell, mounted between the upper jaw and the framework. For generating the CPG, the Simulink model of the Matsuoka Neuron Model, which was formally designed at Massey University, will be come into operation. It will be extended by an I/O interface to communicate with the physical device.

Tuesday, June 24, 2008, 16:30 – 17:00:

MODELLING MUSCLES OF MASTICATION/SKELETAL MUSCLES

O. Röhrle[1] , J.B. Davidson[1], and A.J. Pullan[1,2]

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In previous work, an anatomically realistic model of the masseter muscles and associated bones has been used to investigate the dynamics of chewing. Instead of conventional one-dimensional muscle models, the masseter muscle has been modeled using a three-dimensional biomechanical Finite Element model. The results strongly suggested that, due to the complex arrangement of muscle force directions, conventional skeletal muscle models, e.g. representing the muscles as one-dimensional lines of action, might introduce a significant source of error. One of the model's limitation is the non-physiological lump-parameter approach for the level of activation, in particular the assumption of a constant level of activation throughout the whole muscle.

Within a joint project on functional electrical stimulation of the tibialis anterior a new electromechanically coupled skeletal muscle model has been developed. The above mentioned skeletal muscle model has been enhanced by coupling the cellular responses of skeletal muscles with the three-dimensional biomechanical Finite Element model. To incorporate the cellular properties of skeletal muscle fibres within the whole muscle, homogenised values of key physiological parameters of single muscle fibres, e.g. the pre- and post-power stroke concentration of crossbridge attachments, are computed at the Gauss points of the FE integration scheme. These values are then used to modify the stress tensor in such a way that it resembles the contractile response. Combined with the anatomical structures of fibre and motorunit distributions, such a model can provide a powerful tool to develop neuro-activated skeletal muscle models and, hence, the possibility to refine the results and finding of previous methods.