BioMouth 2012

28th-29th November 2012
The University of Auckland, New Zealand

Room WH418, Piko Building, 49 Wellesley Street East, Auckland

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Symposium Programme

Wednesday, 28th November

9:30 - 10:30	Registration and morning tea
10:30 - 11:40	**Session 1, Chair: Peter Xu**
10:30	Welcome and introduction
10:35	Prof Atsuo Takanishi, Waseda University, Japan **<u>Keynote Speech</u>** "Oral humanoid robotics: applications of humanoid robots to mastication, dentistry, phonetics, music and medical training"
11:35	Discussion and Break
12:00 - 1:00	Lunch
1:00 – 3:00	**Session 2, Chair: Marco Morgenstern**
1:00	Scott Hutchings, Massey University The influence of aging on the use of the TDS technique for the perception of food texture
1:20	Anna Miles, University of Canterbury/University of Auckland A bedside tool for identifying silent aspiration: validating cough reflex testing against instrumental assessment of aspiration and laryngeal sensation
1:40	Haiying Wen, Dalian University of Technology, China Kinematics performance analysis of a jaw movement robot
2:00	Danae Larsen University of Auckland

	Increasing the textural complexity of model foods in order to alter oral breakdown pathways and promote satiation
2:30 – 3:00	Afternoon tea
3:00 - 4:30	**Session 3, Chair: John Bronlund**
3:00	Steven Dirven, University of Auckland Towards robotic esophageal swallowing
3:20	Reham Osman, University of Otago Zirconia implants: a paradigm shift or a passing fad?
3:40	Mingzhu Zhu, University of Auckland Generation of rhythmic and involuntary patterns for a swallowing robot
4:00	Yikun Wang, Auckland Bioengineering Institute Identification of tongue muscle fibre group contraction during propulsion from MR images

Thursday, 29th November

9:00 – 10:00	**Session 4, Chair: Leo Cheng**
9:00	Prof Yuru Zhang, Beijing University of Aeronautics and Astronautics, China **Keynote Speech** "Simulation in a tangible virtual world: haptic interface and its application in a dental simulator"
10:00 – 10:30	Morning tea
10:30 – 12:00	**Session 5, Chair: Kylie Foster**
10:30	Arran Wilson, Institute for Plant & Food Research Limited Video analysis of chewing patterns
10:50	Michael Boehm, University of Queensland The soft matter physics of eating: evolution of food rheology during oral processing
11:10	Chen Cheng, University of Auckland Kinematic analysis of a humanoid masticatory robot
11:30	James Pau, University of Auckland Development of a neuromuscular interface for a jaw exoskeleton
12:00 – 1:00	Lunch
1:00 – 3:00	**Session 6 (**BioMouth Management Committee only)**, Chair: Peter Xu** Workshop discussions – multidisciplinary research and collaboration The way forward – funding and opportunities BioMouth 2014
3:00	Symposium close

Keynote Speech

Oral humanoid robotics: applications of humanoid robots to mastication, dentistry, phonetics, music and medical training

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Even though the market size is still small at this moment, applied fields of robots are gradually spreading from the manufacturing industry to the others in recent years. We can now easily expect that applications of robots will expand into the first and the third industrial fields as one of the important components to support our society in the 21st century. There also raises strong anticipations in Japan that robots for the personal use will coexist with humans and provide supports such as the assistance for the housework, care of the aged and the physically handicapped, since Japan is one the fastest aging societies in the world. Consequently, humanoid robots and/or animaloid robots have been treated as subjects of robotics researches in Japan such as a research tool for human/animal science, entertainment/mental-commit robots or assistants/agents in the human living environment. Over the last decade, some manufactures including famous global companies, such as Toyota, Honda, Mitsubishi Heavy, Tmsuk, etc. have started to develop prototype robots or even commercially available ones for the purposes mentioned above. On the other hand, Waseda University, where I belong to, has been one of the leading organizations of humanoid robot research since the late Prof. Ichiro Kato (1925 to 1994) and his colleagues started to do a research on humanoid robot from the middle of the 1960s. Especially, the WABOT (WAseda roBOT) projects developing the historical whole body humanoid robots that were WABOT-1 and WABOT-2 in the early 70s and 80s respectively are the landmarks in the humanoid robot research history. We are building humanoid robots with three general objectives. The first objective is to create analytical models of human from the view point of engineering (engineering models of humans) based on our study of robots. The second objective is to apply the human models from robotic research to product and system development. And the final objective is to conduct basic research covering the development of future robots for assisting people in everyday life. The first objective is the most important one among the three. We are attempting to scientifically build not only the physical model of a human but also its mental model by developing an anthropomorphic/humanoid robot that functions and behaves like a human. I named it “Robotic Human Science.” Based upon the research philosophy, the late Prof. Kato started to develop the bipedal walking robots as WL (Waseda Leg) series to clarify the mechanism of human bipedal walking in the middle of the 60s. He expanded the research to others such as the arm/hand manipulation as WAM (Waseda Artificial hand and arMs), and even to keyboard player humanoid robot WABOT-2. In the series of humanoid robot developments in Kato Laboratory, I and my colleagues started building of mastication robots which mimic human jaw motion in mastication as WJ (Waseda Jaw) series from 1986. Then, we expanded the research to flute player robots from 1990 as WF (Waseda Flutist), to saxophone player robots from 2007 as WAS (Waseda Saxophonist) series, to speech production robots from 2000 as WT (Waseda Talker) series and to airway management training simulators from 2007 as WKA (Waseda-Kyotokagaku Airway) series all of which relate to human oral mechanisms and functions. In the plenary speech I will introduce the history and the details of those oral humanoid robots.

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Keynote Speech

Simulation in a tangible virtual world: haptic interface and it application in a dental simulator

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Simulation in a virtual world has great potential in the applications in which physical working environments are difficult to create. Examples of such situations are surgical operation, space exploration and maintenance in nuclear environment. To make the virtual simulation more realistic, multi-model feedback including video, audio and haptic have been explored as human-computer interface. Haptic interface is a device which allows us to feel a virtual world by the sense of touch. In surgical simulation, haptic interface is specifically important because haptic feedback is critical to the success of surgical manipulation. Although haptic interface is a promising technology to achieve more realistic virtual simulation, there are still many challenges to overcome. In this talk we will present our research works on haptic interface and algorithms to render haptic feedback. We will focus on how to design and control a haptic device to achieve required performance, and how to render a stable and realistic force feedback from the virtual world. We will discuss these key issues using a dental simulator as an example. We will also discuss some challenges in the development of haptic devices and haptic rendering algorithms.

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The influence of aging on the use of the TDS technique for the perception of food texture

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TDS (Temporal Dominance of Sensations) is a modern technique for monitoring sensory perception that has become widely used in many areas of food research. TDS allows subjects to report dominant sensory sensations throughout the chewing sequence, including the perception of odours, tastes, and textures. It is unknown however whether the TDS methodology can be used in older subjects, which is limiting for those wanting to gain insights in the sensory perceptions of such demographics.

The dynamic perception of food texture by older adults is one aspect of sensory perception which has interest from food manufacturers. As people age there is a natural decline in many biological processes which are important for the dynamic perception of food texture. Cognitive speed, muscular strength, oral coordination, the number of natural teeth, and saliva flow will tend to decline with age, and the number of chews and time required to prepare foods for safe swallowing increases.

Consequently, a study was undertaken to compare the ability of subjects aged 18-30 years with subjects aged 55-70 years to undertake the TDS technique involving the perception of food texture. Each subject took part in a training session, followed by 2 separate TDS sessions. The first TDS session involved reporting dominant textural sensations of similar nuts (peanuts, almonds, macadamia nuts, and cashew nuts), and the second session involved reporting dominant sensations of distinctly different manufactured foods (cheese, shortbread, chocolate, and gelatine gels).

Results show that older subjects successfully undertook the sensory task required, generating typical TDS curves for both sessions. However, some differences in curves were observed between age groups, as were differences in general behaviour in the use of the TDS program, which will be discussed.

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A Bedside Tool for Identifying Silent Aspiration; Validating Cough Reflex Testing against Instrumental Assessment of Aspiration and Laryngeal Sensation.

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Silent aspiration (aspirating without a cough response) is associated with increased prevalence of pneumonia and mortality. The traditional bedside swallowing evaluation does not reliably identify silent aspiration. The aim of this single-blinded correlational study was to determine the accuracy of cough reflex testing (CRT) for identifying silent aspiration using previously validated instrumental measures of aspiration. Cough reflex threshold testing was completed on 181 patients using inhaled, nebulised citric acid (0.4mol/L, 0.6mol/L, 0.8mol/L, 1.2mol/L). Within one hour, 80 patients received a videofluoroscopic study of swallowing (VFSS) and 101 patients received a flexible endoscopic study of swallowing (FEES). All tests were recorded and marked by two researchers who were blind to the result of the other test. In the VFSS cohort, 30% of patients aspirated (24/80) and 70% aspirated silently (17/24). In comparison, in the FEES cohort, a larger proportion of patients aspirated (62%, 63/101) with 57% aspirating silently (36/63). Similar proportions of patients passed CRT in both cohorts (VFSS cohort 75%, FEES cohort 76%). There was a significant association between CRT result (strong, weak or fail) and cough response to aspiration (no aspiration, aspiration with cough, aspiration without cough) for VFSS (X^2 (2) = 11.046, p=.003) and FEES (X^2 (2) = 34.079, p= .000). In patients who were documented to aspirate on instrumental assessment, sensitivity and specificity was optimised at 0.6mol/L in the VFSS cohort (94%, 71% respectively) and at 0.4mol/L in the FEES cohort (69%, 81% respectively). There were a high proportion of overt aspirators who passed CRT (VFSS 86%, FEES 96%) with only 1 overt aspirator in each cohort failing CRT. In patients who failed CRT at 0.8mol/L in the VFSS cohort, there was an odds ratio of 11 for silently aspirating (and an odds ratio of 6 if failing CRT at 0.6mol/L and an odds ratio of 4 at 0.4mol/L). In patients who failed CRT at 0.8mol/L in the FEES cohort, there was an odds ratio of 38 for silently aspirating (and an odds ratio of 25 if failing CRT at 0.6mol/L and 0.4mol/L). CRT is a quick, simple and low cost test of airway sensitivity. In isolation it provides better diagnostic accuracy in identifying silent aspirators than many other isolated components of a clinical swallowing evaluation.

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Kinematics Performance Analysis of a Jaw Movement Robot

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In order to reproduce jaw motions and mechanics that match the human jaw function truthfully with the conception of bionics, a novel human jaw movement robot based on mechanical biomimetic principles was proposed. Firstly, based on the biomechanical properties of mandibular muscles, a jaw robot that simulates the jaw movements is built based on the 6-PSS parallel mechanism. Secondly, the inverse kinematics solution equations are derived. Finally, kinematics performances, such as workspace with the orientation constant, manipulability, dexterity of the jaw robot are obtained. These indices show that the parallel mechanism have a big enough flexible workspace, no singularity, and a good motion transfer performance for human chewing movement.

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Increasing the textural complexity of model foods in order to alter oral breakdown pathways and promote satiation.

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The aims of this study are to evaluate ways in which the structure of a food can be altered to affect the oral breakdown pathway and, in turn, the impact this has on satiation, and potentially satiety.
Current literature suggests that the texture of a food plays and important role in the oral breakdown pathway and sensory perception. Experiments have been conducted on model foods and 'real foods' with different textural properties addressing factors such as bolus particle sizes, bite size, chew rate and oral processing time. Some studies have also linked foods with longer oral processing times with greater expected satiation, increased satiation and enhanced satiety (Bolhuis *et al.*, 2011, Hogenkamp *et al.*, 2011, Mars *et al.*, 2009).
The current study will initially focus on using whey protein/carrageenan mixed gels to create model foods with varying microstructural properties and hence varying textures. These simple gels can then have different food structures added within the gel matrix to increase the textural complexity of the model food. This will determine if foods with more complex textural structures can influence the oral breakdown pathway in a way that promotes longer oral processing and thus positively affects satiation.
Rheological and mechanical properties of the model foods will be assessed as well as the oral breakdown pathways by way of bolus analysis and oral processing using chewing panels and methods such as jaw tracking or electromyography. Temporal dominance of sensation (TDS) testing may be undertaken to build sensory trajectory profiles for the model foods to understand how the sensory perception changes during mastication. This type of sensory data could potentially be correlated to mechanical breakdown properties and jaw tracking and/or electromyography to create a greater understanding of the oral breakdown process. Following this, the sensory attributes and physical properties that have the greatest influence on oral processing time and sensory perception will be examined for their influence on satiation. This will be undertaken by way of *ad libitum* satiation experiments. As a result, the properties that promote faster/increased satiation will be targeted and used to develop modified 'real foods' that influence satiation and in the long term potentially increase satiety.

References:

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Towards Robotic Esophageal Swallowing

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The healthy esophageal swallowing process is observed as a rostro-caudal wave of peristaltic contraction between its sphincteral junctions with the pharynx and stomach. Inspiration has been sought from the manometric and videofluorographic measurement of this process to develop empirically-based specifications for the mechanics of bolus transport. In response to the description of this process a prototype peristaltic actuator has been developed in an effort to robotically mimic esophageal swallowing. The device is of a soft robotic nature which is capable of producing continuous and compliant transport; features which are intrinsic to the biological case. The methods used to characterise the geometrical actuation behaviour of the prototype robotic device are discussed with relevance to interpreting data under the modelled dry swallow condition. This serves as empirical input for a plant model to predict bolus tail geometry for open-loop, dry-swallow actuation. The plant model will be used to generate trajectories which correlate to bolus tail shapes inspired from the medical literature that have been described in mathematics. This modelling is in pursuit of the target application which is to achieve a novel method of assessing bolus transport mechanics in a biologically inspired manner external to the human body. In turn, this presents an opportunity to investigate the interaction between the bolus and wave propagation with repeatable swallowing trajectories.

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Zirconia implants: A paradigm shift or a passing fad?!

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Dental Implants are a well established treatment modality in the management of totally and partially edentulous patients. Different materials have been employed for the manufacture of dental implants. This ranged from polymers, ceramics to metals. Commercially pure titanium and its alloys represent the most attractive metallic materials for fabrication of endosseous implants. Follow-up periods of up to 20 years document a high predictability of titanium implants. Excellent biocompatibility, high corrosion resistance, and good mechanical characteristics have contributed to this. However, controversial reports about titanium corrosion and potential allergic reactions to it; alongside with rising “metal-free” concept in dentistry has propelled the search for an alternative implant material. Ceramic materials were one of those potential alternatives. Pioneer attempts to use ceramics involved the use of aluminium oxide. Nevertheless, the inferior mechanical properties and reduced survival rate of these systems led to its withdrawal from the market. With the development of biomaterial science, industrial technology and introduction of zirconia particularly the yttrium-stabilized tetragonal polycrystalline zirconia (Y-TZP), interest in ceramics as a material of choice has been renewed. Zirconia exhibits good physical and mechanical properties. Stress induced transformation toughening is a unique characteristic of Y-TZP as it undergoes a phase transformation process resulting in local volume expansion therefore counteracting crack propagation. Results of human clinical trials on zirconia implants report a promising outcome in the rehabilitation of partially dentate patients but none exists on using zirconia implants to support overdentures. Thus, our study aimed at evaluating the use of zirconia implants for support of maxillary and mandibular overdentures and comparing it to that of titanium implants.

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Generation of rhythmic and involuntary patterns for a swallowing robot

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Based on medical literatures, swallowing is controlled by Central Pattern Generator (CPG). CPGs are nonlinear oscillators formed by neural circuits which can generate rhythmic movements without receiving central input or rhythmic sensory feedback. These days Matsuoka model has been widely accepted by many robots for generating rhythmic movements. In this paper we intend to present an approach to a swallowing robot control based on a Recurrent Cyclic Inhibition (RCI) circuit. In this design, the RCI consist of three neurons as a CPG to generate rhythmic movement.
In the esophagus, there are two types of peristalsis. First, there is a primary peristaltic wave, which occurs when the bolus enters the esophagus during swallowing. The function of primary peristaltic wave is to force the bolus down the esophagus. Primary peristalsis can be facilitation by sensory feedback trough both cranial and segmental reflex arcs. Second, if the bolus gets stuck or moves slower than the primary peristaltic wave when it is poorly lubricated, stretch receptors in the oesophageal lining are stimulated and a local reflex response causes a secondary peristaltic wave around the bolus, forcing it further down the esophagus, and these secondary waves will continue indefinitely until the bolus enters the stomach. Secondary peristalsis depends on local ganglionic reflex arcs interconnected over the length of the esophagus. There are two kinds of working method under this control system in order to mimic human swallowing process: one is to modelling the behaviour the primary peristalsis, and the other is to imitating the secondary peristalsis. The presented oscillator model could generate stable and nature oscillation. The outputs of oscillator are aiming to control different layers of swallowing robot, but the direct relationship between signals and pneumatic pressure need further research.

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Identification of tongue muscle fibre group contraction during propulsion from MR images

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The tongue is made up of a collection of muscles fibre groups. In the past, large efforts have been dedicated to experimentally investigate functional properties of the different tongue muscles fibre groups, for example, during swallowing. In [1], for example, Napadow et al. investigate internal tongue tissue deformation during propulsion in swallowing using tagged Magnetic Resonance Imaging (tagged-MRI). In this work, they hypothesize that either the co-contraction of the transversus and styloglossus muscles or of the verticalis and styloglossus muscles must be responsible for the large posterior expansion in the anterior-posterior (AP) and superior-inferior (SI) direction. However, the complex fibrous arrangement and challenges in experimentally tracking complex structures and motions on 2D images with a limited field of view raise concerns if the drawn conclusions remain valid. To gain further insights, a computational framework is utilised. The aim was to model the tongue's mechanical behaviour as a response to activating different muscle fibre groups (including the contact with the upper palate) and to compare the computationally determined strains with the experimentally measured ones published in [1]. The best fit provides a good indication which muscle fibre groups in which combination cause the observed strains. For this purpose, a total of thirty-five different muscle fibre group combinations were tested to find the best match. We found that the hypothesized muscle co-contractions responsible for propulsion during dry swallowing are unlikely to drive the most dominant expansion on the tongue's posterior region. The computational experiments suggest that co-contraction of the hyoglossus and the mylohyoid muscles achieve the best match.

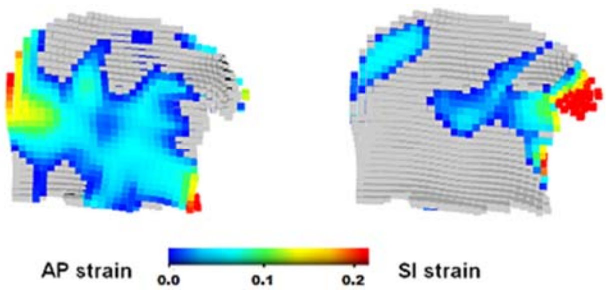

Fig 1: Axial strain distribution in the mid-sagittal plane when co-activating the hyoglossus and the mylohyoid muscle fibre group. Grey represents negative strains.

Reference:

[1] V.J. Napadow, Q. Chen, V.J. Wedeen, and R.J. Gilbert., Biomechanical basis for lingual muscular deformation during swallowing. *AM J PHYSIOL-GASTR L*, 277(3):695–701, 1999b.

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Video analysis of chewing patterns

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The chewing of food is a complex process, combining the physical breakdown of food and mixing it with saliva to form a swallowable bolus, along with a release of flavour to produce a pleasant sensory experience. The details of the process vary greatly among people, and interacts with different food types. But is there a relationship between how people chew their food, their individual chewing strategies, and their sensory perception of that food? Or is even their choice of food determined by their chewing style? Can chewing patterns be grouped into categories? By using a compact digital camera to video people with markers on their chin and nose chewing we have been able to track their chin movement with sufficient accuracy to measure several chewing parameters and relate these to their sensory responses. This simple technique allows the recoding of a large number of individual chewing profiles, which lends itself to the application of data mining techniques to look for the relationships between chewing style and sensory perception. I will describe this work along with the further developments in the automated recording and tracking of chin movement and subsequent analysis.

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The soft matter physics of eating: evolution of food rheology during oral processing

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During consumption, snack foods undergo a transition from brittle solid to soft bolus. This transition plays a role in how such products are perceived and digested with subsequent implications on nutrition and health. While crunchy/brittle foods are not immediately thought of as soft materials, once comminuted to reduce particle size and hydrated by saliva they become a suspension of soft food particles. The resulting soft matter system's rheology is complex but can be understood: the suspension tends to be viscoelastic but yields and flows above a critical 'yield' stress, which is characteristic of soft glasses and gels; for fat containing systems, the oil-in-water emulsion phase impacts the rheology *via* matrix-filler interactions; when snack foods based predominantly on starch are subjected to intense shearing under thin film conditions, the microstructure is irreversibly destroyed leading to an homogenized fluid that exhibits first normal stress differences under shear, characteristic of a polymer solution or melt. In this paper, we demonstrate a novel in vitro approach to understanding the dynamic changes occurring to foods during oral processing by exploring the steps from brittle solid to soft bolus paying particular attention to how the rheology is impacted by microstructural changes during hydration and shear.

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Kinematic Analysis of a Humanoid Masticatory Robot

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Abstract-A humanoid masticatory robot whose main function is to evaluate food properties in a human chewing style is proposed in this paper. Considering the dominant anatomical features of human masticatory system and basing on the previous prototype, a robot that consists of 6-RSS linkages and 2 passive point contract higher-pair constraints simulating human's 6 main chewing muscles and 2 temporomandibular joints (TMJ) respectively is introduced. In essence, the robot is a parallel manipulator with actuation redundancy (PMAR). According to the true masticatory behaviours and characteristics of PMAR, in kinematics, singularity avoidance and workspace are two important factors to be analysed. In dynamics, the optimizations of driving forces distribution among 6 linkages and inner forces in the robot are vital aspects.

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Development of a Neuromuscular Interface for a Jaw Exoskeleton

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A robotic jaw exoskeleton aims to alleviate the physicality of rehabilitation on a therapist by taking over their role of producing repetitive movements. These exoskeletons can move along pre-determined trajectories or follow the intent of the user and move when the user wants to. The difficulty is that users who are not fully able cannot always generate the forces and torques that might be necessary for an exoskeleton to respond to via exteroceptive sensors, such as force or torque sensors. A neuromuscular interface allows user intent to be obtained by using the electromyography (EMG) signal, which is the electrical activity within muscle measured from the skin surface. The signals are present during isometric contractions, and after filtering and processing, they can give an indication of intended muscle activation level. The neuromuscular interface consists of all the hardware and software components involved in obtaining the EMG signal and converting it into an equivalent joint position or torque. We present a physiological model of the masticatory system that has been specifically developed to be driven by surface EMG signals. The model has been developed from the results of EMG studies of the mandibular muscles and biomechanical analyses of the masticatory system.

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