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Kinematics, Motion Control and Force Estimation of a Chewing Robot of 6RSS Parallel Mechanism

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ABSTRACT

Parallel robots have been found in many applications where the work requirements are beyond the capabilities of serial robots. Mouth movements during the chewing of foods are ideally suited to the parallel robot due to relatively high force together with 6 degree of freedom (DOF) motion all occurring in a small workspace. The Massey Robotic Jaw (MRJ) is a life sized mastication robot of 6RSS parallel mechanism designed with human physiology in mind, and to be capable of recreating the movements and forces of human mastication. The MRJ consists of a movable mandible attached to a fixed 'skull' through 6RSS crank mechanisms enabling six degree of freedom motion. In order to perform targeted movements of the MRJ, inverse kinematics of mechanism are solved. Target movements of the lower jaw can then be translated to six individual movements of each actuator. The synchronised motion of all six actuators is implemented using appropriate motion control to create the desired motion at the lower jaw. Motion control in context of the MRJ involves position control during the non-occluding phases of the mastication cycle.

The kinematic and dynamic models of a generic 6RSS robot are discussed and are then simplified considering the special features of a practical chewing robot and the requirements of controller design. The issue of dynamic position and force control of a chewing robot with a 6RSS mechanism is addressed. An impedance control scheme is proposed to achieve the position and force control of the robot. A detailed description on the steps to implement the controller is also presented.

The application of the 6RSS parallel chewing robot to food chewing experiments was described. The force vector applied on the active molar was calculated from the measured torques applied on the six actuators using an analysis of forces through the linkage mechanism. A series of experiments were carried out using model and real foods. The work shows promise for application of the robot to characterise food texture, however a number of future developments are required. To make the robot more human-like, a tongue, cheek and mouth chamber need to be included. Furthermore, accurate force sensing and position sensing of the mandible in Cartesian space is suggested as a means to validate the impedance control method proposed and to verify the force measurement strategy implemented in chapter 6.

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RELATED PUBLICATIONS

- Huang, L., Xu, W. L., Torrance, J., & Bronlund, J. E. (2010). Design Of A Position And Force Control Scheme For 6RSS Parallel Robots And Its Application In Chewing Robots. *Int. J. Human. Robot.*, 7(03), 477-489.
- Torrance, J., Hutchings, S., Bronlund, J., & Huang, L. (2010). Human jaw motion measurement, analysis and robotic reproduction. *International Journal of Intelligent Systems Technologies and Applications*, 8(1), 288-302.
- Torrance, J., Pap, J., Xu, W., Bronlund, J., & Foster, K. (2006). *Motion control of a chewing robot of 6 RSS parallel mechanism*. Paper presented at and in the Proceedings of 3rd International Conference on Autonomous Robots and Agents (ACARA), Palmerston North, New Zealand.
- Xu, W., Torrance, J., Chen, B., Potgieter, J., Bronlund, J., & Pap, J. S. (2008). Kinematics and experiments of a life-sized masticatory robot for characterizing food texture. *Industrial Electronics, IEEE Transactions on*, 55(5), 2121-2132.

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