IN-VITRO TESTING OF KNEE JOINTS USING ROBOTICS: COMPUTER PROGRAMMING THEORY

Natasha K. Lee Shee (B.A.Sc.), James P. Dickey (Ph.D.)
Department of Human Biology and Nutritional Sciences, University of Guelph, Guelph, Ontario, Canada
Email N.K. Lee Shee: nleeshee@uoguelph.ca

INTRODUCTION

The knee is the most used joint in the human body, and thus often succumbs to injury due to trauma and/or aging. Such trauma from accidents, and diseases commonly associated with aging, such as arthritis, can cause pain, inflammation and irregular function of the joint. Studying the knee allows for improved understanding of its injury mechanics as well as knowledge that can be used in improving chemical/surgical treatment of the injured joint and the design of knee prosthetics.

Using robots for *in-vitro* testing of the knee is less invasive than *in-vivo* research while still being able to apply physiologic conditions. The aim of this research is to develop the control theory for controlling a robot to apply physiologic load/motion to the cadaveric knee in order to determine the role and function of each of its structures.

METHODS

An industrial parallel robot (Parallel Robotic Systems Corp., NH, USA) is used, while the knee is described using the floating axis system as described in [1,2,3]. The knee is manipulated by manipulating the tibia (secured to the robot) about the femur (secured to ground) (Figure 1). Local co-ordinate systems are defined through digitizing of the proximal tibia, distal femur, end-effector and load cell. Position and load control programs were then written in Matlab 7.0 to track the mathematical transformations between the systems in order to control the robot kinematics with respect to the knee kinematics and load cell kinetics [2,4]. These programs allow the user to specify either knee kinematic targets or knee kinetic targets respectively.

Both programs were verified using linkage systems that modeled the knee. The position control and load control programs were tested using artificial constructs.

RESULTS AND DISCUSSION

The position control program can reach the target knee kinematics within 0.1^{o} and 0.01mm. To incorporate the floating axis description of the knee, the program recalculates the position/orientation of the floating co-ordinate system after every 0.2^{o} and 0.1mm increment of knee motion. This allows for a step-wise generated position path for the end-effector that can be saved and replayed in a more fluid fashion.

Currently, the load control program can reach the target knee kinetics within 3N and 0.5Nm. Kinetics read at the load cell (secured to the femur) are mathematically transformed to the knee co-ordinate system to represent the knee kinetics [4]. Target knee kinematics are then calculated using its kinetics

Figure 1: Testing set-up. Tibia is secured to the parallel robot (top) and the femur is grounded (bottom).

and a compliance matrix. When the knee reaches the desired kinematics, its kinetics are checked, the compliance matrix is updated; if necessary, new target knee kinematics are set and the process reiterates until the target kinetics are reached.

The position and load control programs are stepping stones for a hybrid control program that simultaneously controls both knee kinematics and kinetics to enable physiological joint loading. This program will allow the user to specify which degrees of freedom are controlled in load and which in position, and is currently being developed.

CONCLUSIONS

Preliminary tests confirm that knee kinematics and kinetics can be controlled independently using the commercial robotic system. When hybrid control programming is complete, physical testing using cadaveric knees will begin.

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