JOVE Pilot Research Study in Astronomy and Microgravity Sciences

Final Technical Report

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Project Summary

The purpose of this project was to develop hardware and software facilities for evaluating the biomechanical interactions between human hands and space suit gloves. The first task was to measure finger joint angles inside space suit gloves. A preliminary survey identified three potential systems which could be used in the proposed study. These are manufactured by VPL, Virtual Technology and GreenLeaf Medical Systems.

In response to the current market situation, a glove for measuring the positions of the hand inside a space suit has been developed at Vanderbilt University, funded by the JOVE program. We have constructed a prototype of the glove to demonstrate its sensing technologies.

There are two types of sensors in the glove. The positions of the fingers are measured using bend sensors based on the CyberGlove design. This sensor consists of two strain gages mounted to a 0.003 inch thick mylar sheet. The sensor is encapsulated using 0.001 inch kapton film to give it sufficient rigidity. A long gage is used to average the strain generated in the sensor due to bending. This average strain produces an output signal proportional to the angle of the bend.

The force sensor, FSR, is manufactured by Interlink. It consists of conductive ink sandwiched between two plastic sheets. An electrode is printed on one of the plastic sheets using silver ink. When the electrode makes contact, current flows through the conductive ink. The resistance of the ink pad is sensitive to pressure.

We have also developed circuits for exciting and measuring the sensors. The current version requires a single sided twelve volt power supply which is one inch long and 0.4 inches in diameter.

The current glove prototype is constructed from medium weight lycra polyester. The glove provides pockets for mounting the sensors on the back of the fingers and palm.

Data generated by the glove will be analyzed using biomechanical models of the hand. Vanderbilt is developing software tools to generate these biomechanical models using magnetic resonance imagery (MRI). Using MRI, we can obtain detailed pictures of muscle, ligament and bone structures.

The software tools provide three basic functions. The first is to aid development of biomechanical models from MRI (or computed tomographic) data. Image processing tools are provided for filtering and segmenting the data. The software implements spline fitting tools, called snakes, to compute the boundaries of anatomic objects in the planar images. This provides three dimensional surface models of the bone and muscle geometry.

The software also furnishes facilities for assembling the biomechanical information into models which can process information generated by the glove. This component uses a display list data structure to combine geometric information obtained from the MRI data with joint kinematic data. We can determine the motions of the joints using several MRI data sets. Kinematic maps provide a method of interpolating between the calibration positions of the bones obtained from each MRI data set. Smooth curves in the eight dimensional image space of the kinematic map represent smooth three dimensional motions. Spline functions interpolate curves through the data points, providing a means to interface the ROM glove with the biomechanical model.

Finally, the software provides facilities to visualize and analyze results of experiments performed with the glove. Among these tools will be calculations of the torque generated at each joint. The display will show the position of the hand along with a graphical representation of the magnitude of the forces being applied to the hand. We will develop additional tools as we gain experience with the glove.

The current state of the software facilities is incomplete. We have implemented the tools for processing the MRI (or CAT) data sets, and have a basic means for assembling the biomechanical model. The interface between the data glove and the software has not been implemented, including the kinematic maps used to interpolate the calibration positions.

The software tools are implemented on a Silicon Graphics Indigo^2 Extreme graphics workstation. This 100MHz RISC workstation has 32 Megabytes of RAM, 1 Gigabyte of disk space and provides 24 bit color graphics acceleration. The software is implemented in C++ using object oriented techniques.

Education Outreach

The project has sought the involvement of undergraduate students. Three undergraduates eventually participated. These students were involved in programming the microcontroller and developing techniques for fabricating the sensors.

Publication Issued During the Course of the Research

Refereed Journal Publications

1. "A Feasibility Study of Hand Kinematics for EVA Analysis Using Magnetic Resonance Imaging," with R.D. Dickenson, C.H. Lorenz, A.M. Strauss, and J.A. Main, accepted for publication in SAE Transactions.

2. "An Anthorpomorphic Hand Exoskeleton to Prevent Hand Fatigue During EVA," with B. Shields, J.A. Main, and A.M. Strauss, accepted for publication in IEEE Transactions on Systems, Man and Cybernetics.

Refereed Technical Papers

1. "Magnetic Resonance Imaging as a Tool for Extravehicular Activity Analysis," with R. Dickenson, C. Lorenz, A. Strauss, and J. Main, IAA Paper No. IAF/IAA-92-0254, presented at the 43rd Congress of the International Astronautical Federation, Washington, DC, August 28 - September 5, 1992.

2. "Design and Control of a Hand Exoskeleton for Use in Extravehicular Activity," with R. Shields, J. Main and A. Strauss, IAA Paper No. IAF/IAA-93-I.5.252, presented at the 44th Congress of the International Astronautical Federation, Graz, Austria, October 16-22, 1993.

3. "Design and Control of Exoskeletons for Planetary Exploration," with B.L. Shields, J.A. Main, and A.M. Strauss, SAE Technical Paper No. 951729, presented at the 25th International Conference on Environmental Systems, San Diego, CA, July 10-13, 1995.

Masters Candidates

Reuben Dickenson	An Invivo Biomechanical Study of the Hand Using Magnetic Resonance Imagery, 1992.
Robert Shields	The Design of an Exoskeleton Glove for Extravehicular Assembly Tasks, 1993.
Susan Ward	Biomechanical Modeling of the Interaction of Hands and Space Suit Gloves, 1996.