HUMAN GRASP KINEMATICS REDUCTION: INFLUENCE OF THE SIZE AND WEIGHT OF THE GRASPED OBJECT

J.L. Sancho-Bru, M. Vergara, N.J. Jarque-Bou, A. Pérez-González, F.J. Andrés

Departament d'Enginyeria Mecànica i Construcció, Universitat Jaume I, Castelló, Spain

Introduction

Current research in hand prosthetic devices and Robotics tries to emulate the dexterity and stability of the human hand during the manipulation and grasping of objects [Weir, 2007]. The complexity of the human hand grasp results in a challenging control problem, which is even more severe when dealing with prostheses that have to be controlled through EMG signals. In an attempt to make the problem affordable, some authors have proposed the use of postural hand synergies [Weiss, 2004] to reduce the effective degrees of freedom of the hand. However, to date, the effect of the object size and weight on this reduction and its implications in the control algorithms has not been addressed.

Methods

We analysed the grasping postures adopted by 5 healthy subjects when asked to grasp and transport four cylinders of the same weight (469g) and different diameters (35, 50, 65 & 90mm) and four cylinders of the same diameter (50mm) but different weight (193, 469, 780 & 1117g). The subjects performed 3 grasps on each cylinder: without any indication of the type of grasp, with a pinch grasp involving all fingers, and with a cylindrical power grasp. Each grasp was repeated 3 times, and the grasping postures were obtained by tracking the location of 29 markers on the subjects' hands (Fig. 1) using a motion capture system (Vicon®). Each posture was defined by 23 joint angles: flexion of all interphalangeal (IP) joints, flexion and abduction of all metacarpophalangeal (MCP) joints and thumb carpometacarpal (CMC) joint, and flexion of ring and little CMC joints.

To reduce the kinematics dimension of the grasp, a factorial analysis based on principal component analysis (PCA) with eigenvalues >1 was performed. Then, the calculated factors were used as dependent variables in a MANOVA with grasp type, weight and diameter as fixed factors.

The results implication on the development of control algorithms was analysed.

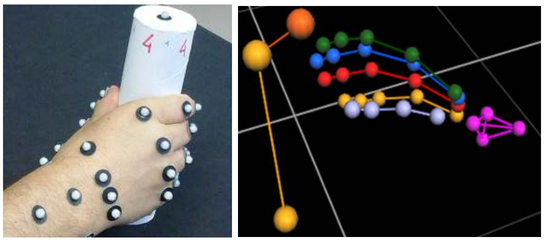

Figure 1: Markers registered

Results

Five factors (F1 to F5) accounted for 77% of the variance. F1 represents flexion of all IP joints and thumb MCP and CMC joints. F2 shows flexion of all finger MCP joints. F3 represents a coordinated abduction of all MCP joints and thumb CMC joint. F4 allows the palmar arching through the flexion of ring and little CMC joints. And F5 shows a coordinated MCP extension with IP flexion of thumb.

Significant differences were observed between grasp types for F1 and F2 and between diameters for F1, F2 and F5. No significant difference was observed between weights. Furthermore, the interaction *grasp type x diameter* was also significant for F1.

Discussion

For the grasps studied, the algorithms to control F3 and F4 don't require to consider the grasp type, weight and diameters, while the control of F1 and F2 should consider grasp type and diameters. Moreover, a different control strategy is required for each grasp type, as the interaction *grasp type x diameter* was significant for F1. F5 is the least important and must consider diameters for its control. More research is needed to include a wider range of grasp types and object shapes and weights.

Acknowledgements

Work supported by the Spanish Research & Innovation Ministry and the EU (FEDER funds) through the project DPI2010-18177.

References

Weir *et al*, 29th Int Conf IEEE, 4359-60, 2007.

Weiss *et al*, J Neurophysiol, 92:523-35, 2004.