3-DIMENSIONAL KINEMATIC MODEL FOR PREDICTING HAND POSTURE DURING CERTAIN GRIPPING TASKS

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INTRODUCTION

Hand posture has a pronounced effect on hand grip strength in a given work condition. Even though many studies have addressed hand grip strength capacity, relatively few models have quantitatively explained how hand posture affects grip strength. Buchholz predicted the posture by iteratively increasing joint angles until ellipsoidal finger segment contacts an ellipsoid representing object [1]. Lee suggested a hand posture prediction model using optimization [2]. In the model, he minimized objective function which is summation of distances from center of rotation to the object surface. In this paper, a model for simulating hand posture by use of a contact algorithm has been developed. The distances between object surface and finger segments were calculated as increasing joint angles successively. This model has advantages over the previous models, in that it can estimate hand posture during real grasping scenarios and it considers the effect of finger movement patterns on hand postures. It can also be applied to various types of grips.

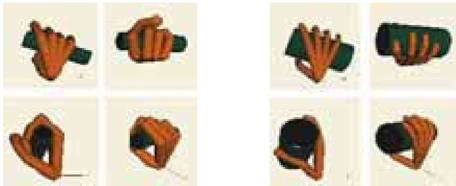
METHODS

The computational model was developed in a Visual C++ environment and OpenGL graphic functions were used to display the hand and object. The hand was modeled as open chain of rigid body segments, which was described as a truncated cone, the simplest reasonable representation of hand segments. 25 degrees of freedom were used to characterize the joints of the five fingers and wrist. A collision detection algorithm was used to determine when contact occurred between hand and object. Quadratic surface meshes were created for the surfaces of both hand and object. The distance between the meshes on hand and those on object was calculated as the joint angle increased. When the minimum distance between hand and object was smaller than a preset threshold value, it was regarded as a collision occurrence.

Two subjects participated in the experiment. Independent variables considered in this experiment were: 1) object size (cylinder diameter: 26.2mm, 60.0mm, 114.3mm); 2) hand size (hand length/breadth: 192/85.5mm vs. 171/91.0mm). Object location and elbow angles were controlled. Joint angles of each joint were measured for each condition. Each condition was repeated five times for each subject. The markers secured on dorsal side of the hand were tracked by OptoTrak® Certus™ motion tracking system (Northern Digital Inc.).

Table1 Mean(SD) values of the model prediction error of difference between observed and predicted joint angle(Middle finger, 2 subjects, 6 trials per subject)

Diameter	MCP	PIP	DIP
26.2mm	-3.9°(2.4°)	9.1° (1.6°)	-24.3° (12.2°)
60.0mm	1.0° (1.6°)	4.5° (2.0°)	5.2° (4.6°)
114.3mm	-5.1° (1.4°)	7.9° (1.4°)	-5.0° (7.1°)



(a) **(b)**

Figure 1: Predicted prehensile postures for different object and hand sizes. Left (a): a 95% male hand grasping a 20 mm diameter cylindrical object. Right (b): a 25% female grasping a 40 mm diameter cylindrical object.

RESULTS AND DISCUSSION

Table 1 shows the model prediction error between observed and predicted joint angle for varying cylindrical object sizes. The hand model gave reasonable predictions of joint angles for different object sizes (R^2=0.79). The errors between observed and predicted joint angle ranged from -24.3° to 9.1°. The greatest error was found in the small object size. For the larger sized objects, errors ranged from -5.1° to 7.9°. Joint angles appear to be very sensitive to object location for the small object.

Figure 1 shows different views of grasping objects when 1) a 95% male grasps a 25 mm diameter cylinder; 2) a 25% female grasps a 50 mm diameter cylinder, which were simulated by the computational model.

By applying a simple contact algorithm, prehensile hand postures could be predicted for various object attributes and hand size; however, because this model considered only kinematic relationship, the effects caused by force were not included. The rigid body modeling of the hand without assessing deformation also could also result in errors, probably overestimating angles. The effects of the object location on the hand posture will be studied in the future.

REFERENCES

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