PREDICTION OF HAND FORCES AND MOMENTS USING NEURAL NET MODELING OF GROUND REACTION FORCES AND KINEMATIC DATA

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INTRODUCTION

Occupational biomechanical models require reasonably accurate hand forces and moments to sequentially compute joint reaction forces and moments through the body producing ground forces and moments. We have pursued development of Artificial Neural Network (ANN) models to predict independent hand forces and moments using limited postural data and measured ground reaction forces. This paper summarizes our initial findings regarding the validity of the proposed modeling schema.

METHODS

Subjects

Six male and four female subjects between 20 and 32 years of age, with material differences in stature and body mass, participated in this study on an informed consent and paid basis.

Apparatus

Posture data was obtained with an eight-camera Peak Performance™ Videokinematic system that sampled kinematic data at 100 Hz. Twenty-one 25mm-diameter reflective markers were placed bilaterally [1]. Standard methods were used to obtain Cartesian space recordings of subject centers of mass and centers of pressure during recording trials [2].

Hand forces and moments were recorded from ATI (Industrial Automation, Apex, NC) six-dof force/torque (F/T) sensors were sandwiched between a load of 10 Kg load and a set of cylindrical handles. The F/T sensors were sampled at 16 bits and 600 Hz. Ground reaction forces were obtained from two Kistler force plates (Model 9286a) that were sampled with 12 bit accuracy at 600 Hz. All analog data was filtered with a 10 Hz low-pass Butterworth filter and the marker data was filtered with a 6 Hz low-pass Butterworth filter.

Procedures

Subjects were asked to stand on two independent force places, grasp the load with instrumented handles, and to "dance" randomly with the load as they lifted, lowered, pushed, pulled, twisted and turned as randomly and dynamically as the subject felt would be safe for them. A second trial included standing with coronal plane performing "steering wheel" movements of the load and a third trial standing transverse plane "steering wheel" load movement.

Analysis

Twelve local Cartesian hand force and moment response variables obtained with the combined three trials were trained using included joint angles or marker loci, centers of mass and pressure, and globally-referenced Cartesian ground forces and moments as predictor variables. The Artificial Neural Network (ANN) architecture selected for supervised training consisted of a fully-connected single-hidden-layer Multilayer Perceptron (MLP) network with 18 Perceptron Elements (PEs) in the hidden layer. The individual hand force-moment predictor ANNs were created using 18,000 records to train, approximately 6,000 records to test, and cross-validation was performed with predicted and actual forces and moments using 6,000 fresh samples.

RESULTS

The following are representative plots of 6,017 cross-validation of ANN predictions of hand forces and moments are representative of the global reference hand forces and moments in the cross-validation analysis. Fx,Fy,Mx and Mz crossvalidations are similar but less accurate because of smaller magnitudes.

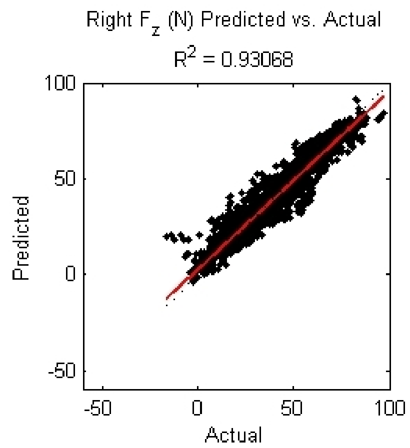

Figure 1. Representative plot of predicted v actual vertical (Fz) hand forces for right hand.

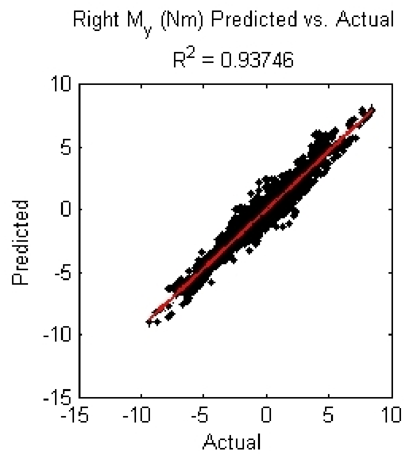

Figure 2. Representative plot of predicted v actual moments about hand y-axis.

CONCLUSIONS

Results are encouraging in terms of the feasibility of using AAN models to accurately predict independent forces and moments within each hand during very dynamic behaviors.

REFERENCES

1. Vaughan CL, Davis BL, O'Connor J (1992) Dynamics of Human Gait. Human Kinetics Press, Champaign Illinois.
2. Chaffin, D., Andersson, G. and Martin, B. (2006) Occupational Biomechanics. Wiley & Sons: New York.