AN ARTIFICIAL NEURAL NETWORK TO PREDICT WHOLE-BODY 3D POSTURE DURING DYNAMIC LOAD-REACHING ACTIVITIES

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Introduction

Human body motion data are essential inputs for biomechanical models to estimate body joint/muscle forces and for ergonomic risk assessment tools to assess risk of injury during occupational activities [1,2]. Motion data are usually measured via costly equipment such as motion capture systems or RGB cameras [3]. As alternatives, several artificial neural networks (ANNs) have been developed to predict human body movements during different one- and/or two-handed lifting activities [4-7]. However, all these models are only able to predict the posture statically at the load-reaching point [4-6] or during the dynamic load-moving phase [7], while each load-handling activity also includes a dynamic load-reaching (from neutral upright standing posture) phase. This study, therefore, aimed to develop an accurate easy-to-use machine learning-based model to predict human body posture in one- and two-handed dynamic load-reaching activities.

Methods

Twenty healthy right-handed male subjects (body mass indexes between 18 and 26 kg/m^2) participated in this study [6]. Each subject performed 204 one- and two-handed load-reaching activities (without any hand-loads) from neutral upright standing posture to seven vertical (0 to 180 cm from the floor) and fifteen horizontal (30 to 60 right/left lateral and/or anterior) reaching points while adapting four different lifting techniques: upright standing, stoop, semi-squat- and full-squat [6]. Meanwhile, their full body motion was recorded via a ten-camera Vicon motion capture system at a sampling rate of 120 Hz using full-body plug-in gait marker placement standard with forty-one skin markers [6]. The 3D trajectory data of each marker was resampled to 101 frames (0 to 100 percent of the load-reaching duration) for each of the performed tasks and a dynamic posture dataset with 412,080 observations (20 subjects × 204 tasks × 101 frames) including 3D trajectory data of forty-one markers was constructed. Using this dataset, an ANN with nine input parameters (subject's body mass, body height, 3D coordinates of the final reaching point, adapted lifting and handling (one- or two-handed) techniques, time duration of each task, and the frame number between 0 to 100) as well as 123 output parameters (3D coordinates of forty-one markers) was developed. The number of hidden layers and their neurons were also set using trial and error approach to reach the least prediction error. Finally, the generalization performance of this ANN was evaluated using both random-hold-out validation (RH, with 70-15-15% of data for, respectively, training, validating, and testing) and leave-one-subject-out (LOSO) cross-validation methods [6].

Results

The final trained/validated/tested ANN contained two hidden layers with, respectively, 650 and 850 neurons in each layer. The prediction performance of the developed posture prediction ANN is presented in Table 1 in terms of root-mean-square-error (RMSE) and normalized-RMSE (to the range of data, nRMSE) for the whole body and for different body segment output markers.

Output segment	RH		LOSO (mean±SD)	
	RMSE (mm)	nRMSE (%)	RMSE (mm)	nRMSE (%)
Head	23.0	3.2	49.2±6.7	8.9±0.5
Body-pelvic	16.9	4.2	35.3±4.3	7.6±0.4
Arms	46.5	6.7	52.7±4.8	9.3±0.5
Legs	10.2	4.8	26.5±5.0	4.9±0.4
Whole-body	29.9	5.3	41.5±5.0	7.7±0.4

Table 1: The prediction performance of the final ANN, when compared to the measured motion data, in terms of RMSE and nRMSE using both RH validation and LOSO cross-validation methods.

Discussion

Comparing our RH validation results to the most accurate ANN for predicting final static posture during load-reaching activities, the new ANN was found more accurate in predicting head, body-pelvic, and leg postures [6]. The new ANN was not, however, able to predict arms posture as accurate as the previous ones. This was because one-handed tasks were carried out by the right hand while the left hand was free to move so that its position was hard to be predicted by the ANN. By using this new developed ANN along with the previous ones for predicting the final static posture during reaching [6] and the dynamic posture during load-moving phase [7], the human whole-body posture can be predicted during the entire load-reaching/lifting activities with accurate easy-to-use machine learning-based models instead of using costly and time-consuming measurement equipment.

References

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