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An Artificial Neural Network to Predict Whole-Body 3D Posture During Dynamic Load-Reaching Activities

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INTRODUCTION

Motion data is an essential input to estimate body forces to assess risk of injury during occupational activities [1,2]. It is usually measured via costly equipment such as motion capture systems or RGB cameras [3,4]. As alternatives, several artificial neural networks (ANNs) have been developed to predict body movements during one- and two-handed lifting activities [5-8]. However, all these models are only able to predict the posture statically at the load-reaching point [5-7] or during the dynamic load-moving phase [8], while each load-handling activity also includes a dynamic load-reaching (from neutral upright standing posture) phase. This study, aimed to develop an accurate easy-to-use ANN to predict human body posture in one- and two-handed dynamic load-reaching activities.

METHODOLOGY

Twenty healthy male individuals each performed 204 one- and two-handed load-reaching activities from neutral upright standing posture to seven vertical (0 to 180 cm) 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 [7] (Figure 1). Meanwhile, their motion was recorded via a Vicon motion capture system using forty-one skin markers of full-body plug-in gait standard [7]. The 3D trajectory data of each marker was then resampled to 101 frames for each task. An ANN with nine input as well as 123 output parameters was then trained (Figure 2). 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 [7].



Figure 1. Marker placement and different performed load-reaching tasks.

RESULTS

The trained ANN contains two hidden layers with, respectively, 650 and 850 neurons. The prediction performance of the developed 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.

Table 1. The prediction performance of the final ANN

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**

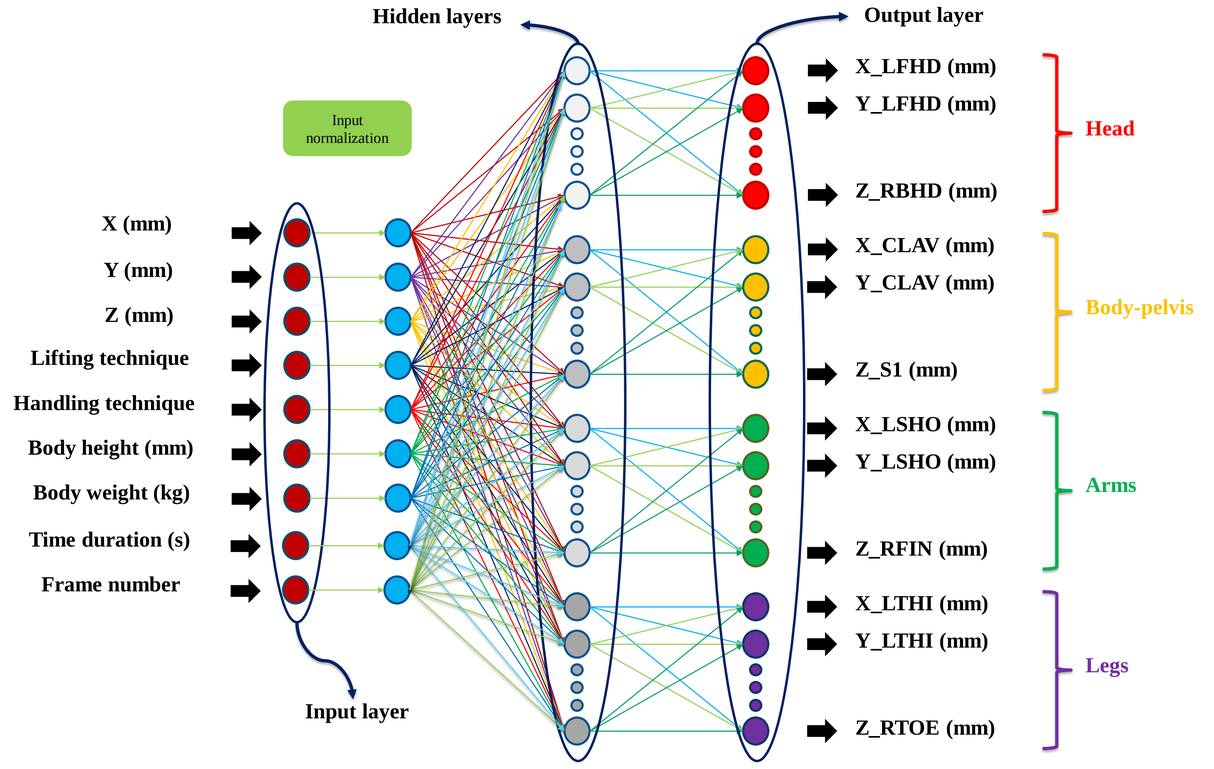


Figure 2. The architectures of the developed ANN.

CONCLUSIONS

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 [7]. The new ANN was not, however, able to predict arms posture as accurate as the previous ones. This was since 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 [7] and the dynamic posture during load-moving phase [8], 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 equipment.

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