

Vertical Ground Reaction Force and Center of Pressure Prediction During Lifting Activities Using Machine Learning

Sajjad Daroudi, Seyede Niloofar Hosseini, Mahdi Mohseni, Mohamad Parnianpour, Navid Arjmand

Department of Mechanical Engineering, Sharif University of Technology, Tehran, Iran

INTRODUCTION

Ground reaction forces (GRFs) and centers of pressure (CoPs) are essential inputs in musculoskeletal models [1]. While these are usually measured via force-plates, they can also be predicted based on motion data, developed in AnyBody Modelling System (AMS) thus eliminating the need for costly laboratory equipment [2]. However, AMS is a hard-to-use and expensive software. This study, aims to develop easy-to-use yet accurate artificial neural networks (ANNs) based on AMS outputs to predicts vertical GRFs (GRFz) and CoPs during various manual handling (MH) activities.

METHODOLOGY

Ten healthy male individuals each performed 204 one- and two-handed load reaching tasks at, respectively, 15 and 7 horizontal and vertical load locations while adapting four lifting techniques: upright standing, stoop, semi-squat, and full-squat [3]. Meanwhile, body motion data was collected via Vicon motion capture system and full-body plug-in gait marker placement [4,5]. Nine different hand loads (0 to 30 kg) were modeled using a full-body AMS model while assuming identical postures for different hand loads [3] (Figure 1). GRFz and CoPs were estimated for each task using the AMS validated GRF prediction model [2,6]. Two ANNs were trained to predict GRFz and CoPs of both feet during different activities considering eight simple input parameters using the predicted GRFz and CoPs dataset (Figure 2). Using random hold-out method with 70-15-15% of the dataset for, respectively, training, validation, and testing, the ANN architectures were designed by Optuna framework to achieve the highest accuracy [7,8]. Moreover, the performance of the developed ANNs were evaluated via leave-one-subject-out cross-validation method [3].

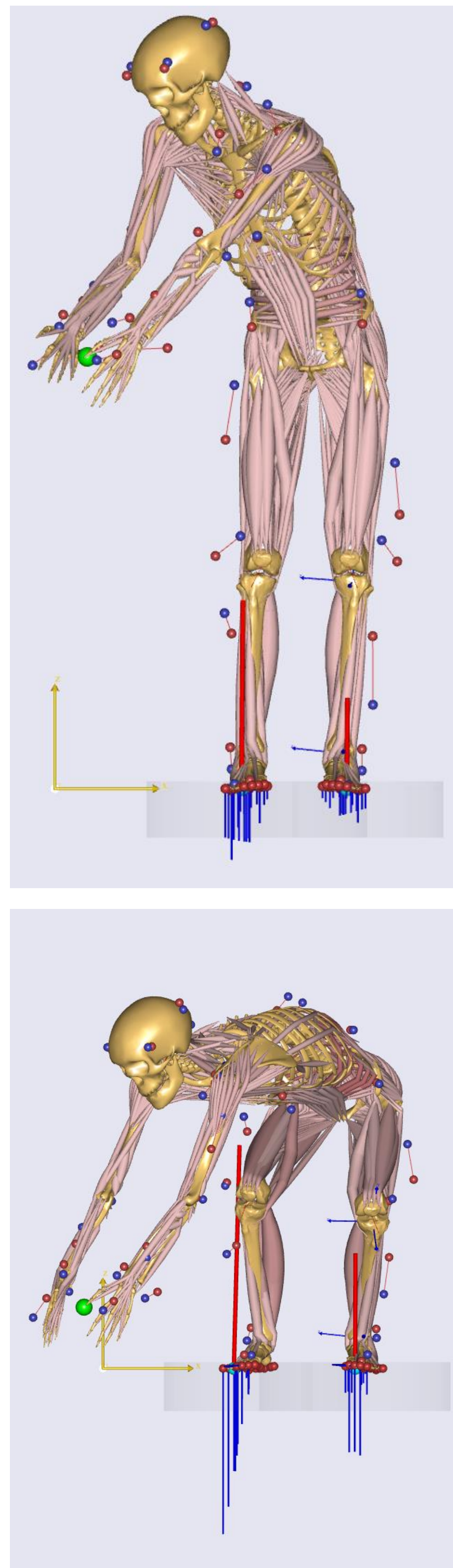


Figure 1. Using AMS to predict GRFz and CoPs.

RESULTS

Table 1. The ranges of AMS modeling results and the prediction errors of the ANNs.

Output parameter	Range	RMSE (mean±SD)	nRMSE (mean±SD, %)	R ²
Right GRFz (N)	0-1163	65 ± 17	5.6 ± 1.5	0.97
Left GRFz (N)	0-1040	64 ± 18	7.6 ± 2.2	
Right CoPx (mm)	26-509	38 ± 10	7.8 ± 2.1	0.77
Right CoPy (mm)	-60-300	31 ± 8	8.6 ± 2.3	
Left CoPx (mm)	-251-535	102 ± 19	13.1 ± 2.4	
Left CoPy (mm)	-50-305	39 ± 5	10.9 ± 1.6	

Both GRFz and CoP ANNs had the same architecture including 3 hidden layers with 50, 50, and 25 neurons (Figure 2). The range of predicted GRFz and CoP values from AMS modeling as well as root-mean-square-error (RMSE), normalized-RMSE (to mean value of the data, nRMSE), and R² of the trained ANNs for GRFz and CoPs are presented in Table 1.

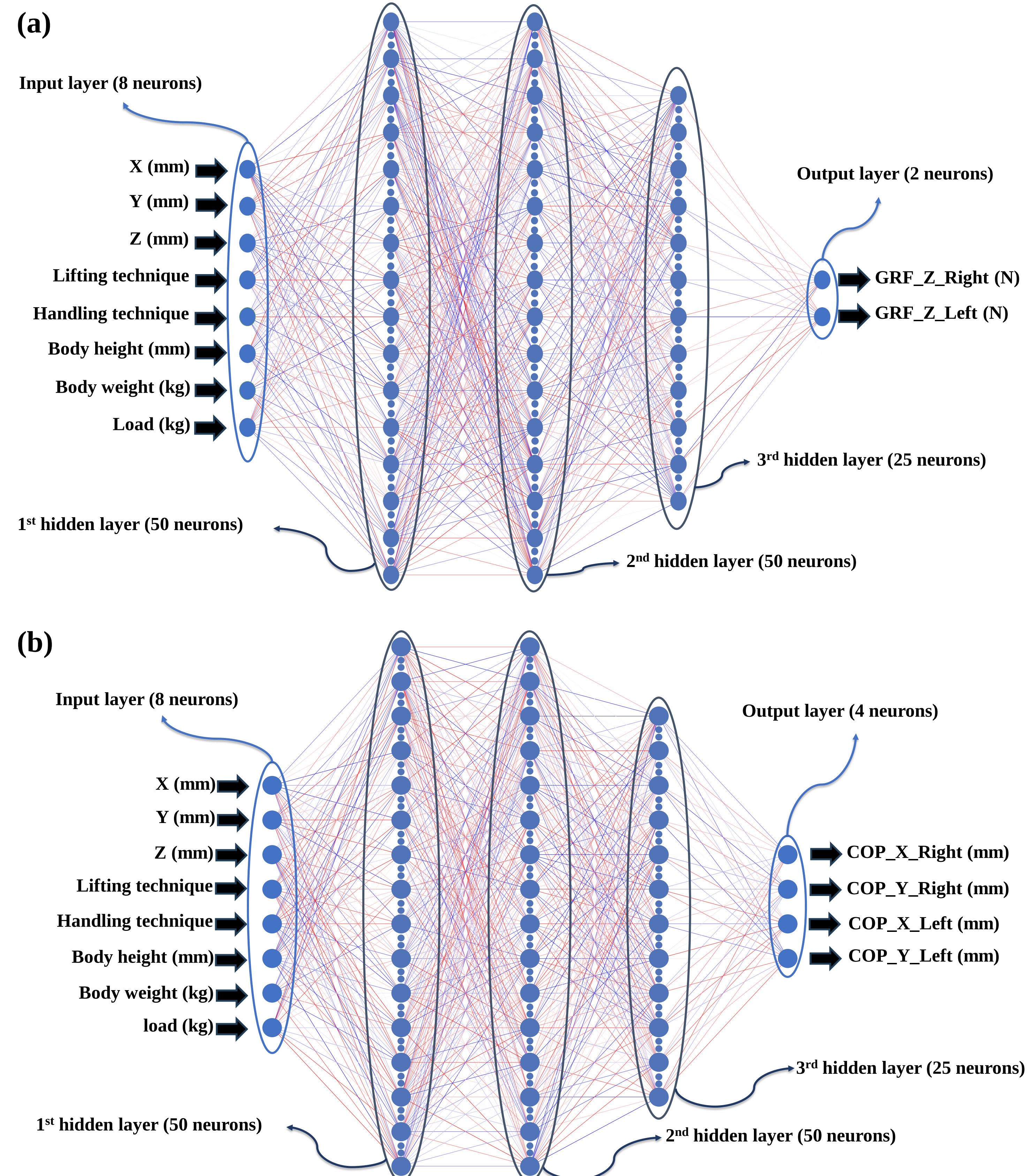


Figure 2. The architectures of (a) GRFz and (b) CoPs ANNs.

CONCLUSIONS

Overall, the trained ANN for predicting GRFz was more accurate than the ANN for CoPs (Table 1). Using these new easy-to-use yet accurate GRFz and CoPs prediction ANNs, there will be no need to use hard-to-use models such as AMS or expensive measurement tools like force-plates to evaluate these parameters. However, it should be noted that these ANNs are developed based on the predicted GRFz and CoP values of AMS thus the prediction errors are included in these new prediction ANNs. In addition, assuming identical body posture while handling different hand-loads would compromise the model prediction performance [3]. Future studies, therefore, should be focused on evaluating the accuracy of these ANNs using laboratory collected GRFz and CoPs data for all hand-loads.

REFERENCES

1. Daroudi et al, CMBBE Symposium, Abstract book (posters): 64, 2023.
2. Daroudi et al, J Biomech, 164: 111974, 2024.
3. Mohseni et al, J Biomech, 162: 111884, 2024.
4. Hulleck et al, Res Square, 2023.
5. Hulleck et al, IEEE Tran Neur Sys Rehab Eng, 32:1715-1724, 2024.
6. Larsen F et al, Ann Biomed Eng, 48: 805-821, 2020.
7. Mohseni et al, J Biomech, 131: 110921, 2022.
8. Akiba et al, Proc of the 25th ACM SIGKDD Int Conf, 2623-2631, 2019.

CONTACT

If you have any questions about this research, please contact us via:

mahdi.mohseni9776@gmail.com