Enhancing Accuracy in Accessible Motion Capture Technology

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Introduction

Accurate biomechanics data can dramatically improve healthcare and human movement research, yet current motion capture tools are inaccessible due to cost and time commitments (see Fig 2) outside the laboratory. The recently released OpenCap Biomechanics Platform [1], makes strides in accessibility, but has poorer accuracy than marker-based (MoCap) alternatives (see Fig 1). This research sought to fix those issues.

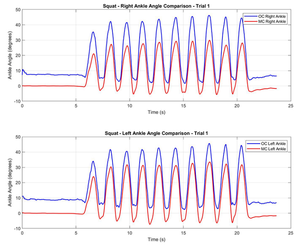

Fig 1. Comparison of OpenCap and MoCap Recordings

Methods

Paired data collection with OpenCap and MoCap was conducted on 10 male subjects aged 18 - 29. Each subject performed 10 lower-body exercises, 10 repetitions per set and 3 sets per exercise. The exercises were as follows:

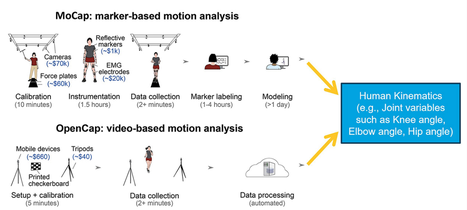

Fig 2. Experimental Setup for MoCap and OpenCap Data Collection [1]

1. Squat	2. Forward Lunge	3. Goblet Squat	4. Lateral Lunge	5. Plié Squat
6. Vertical Leg Raise	7. Curtsy Lunge	8. Step Up	9. Backward Lunge	10. Hamstring Curl

A machine learning model was then trained using 10 fold cross validation with the current architecture described in Fig 3.

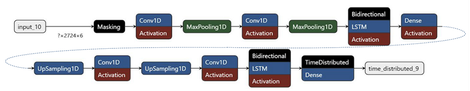

Fig 3. Machine Learning Model Architecture for Data Correction

Results

The MAE was calculated per joint per exercise, per joint across exercises, per exercise across joints, and across all trials. The error between observed OpenCap and MoCap and the error between our model's predicted MoCap data and MoCap are recorded in Table 1 and Table 2 respectively.

Evaluating the OpenCap Platform by the acceptable error level proposed in their paper of 8° (based on MoCap's error range) [1], we found 15 instances where the MAE of a joint across 10 subjects for an exercise was greater than 8° (highlighted in red) and 1 instance where the mean MAE for a joint across all exercises was greater than 8° (Hip Flexion L). Conversely, our model had 0 instances of either case.

Table 1: MAE between Observed OpenCap and MoCap Across 10 Subjects

Exercise	MAE Knee R (°)	MAE Knee L (°)	MAE Ankle R (°)	MAE Ankle L (°)	MAE Hip Flexion R (°)	MAE Hip Flexion L (°)	Mean MAE Across Joints (°)
Backward Lunge	3.63	3.18	7.53	8.17	7.66	7.54	6.29
Curtsy Lunge	4.63	4.24	7.69	9.87	8.19	9.24	7.31
Forward Lunge	4.34	4.33	6.90	7.39	7.14	7.24	6.22
Goblet Squat	4.37	3.86	4.98	4.63	7.71	8.28	5.64
Hamstring Curl	3.83	3.66	7.38	8.37	6.36	6.71	6.05
Lateral Lunge	4.62	4.25	6.17	6.33	6.74	7.76	5.98
Plie Squat	4.21	3.04	5.88	5.20	9.11	8.97	6.07
Squat	3.55	3.40	7.97	10.10	9.80	11.92	7.79
StepUp	4.49	3.65	5.57	5.27	5.98	5.83	5.13
VLegRaise	4.64	4.04	8.37	8.82	8.15	9.11	7.19
Mean MAE Across Exercises	4.23	3.76	6.84	7.42	7.68	8.26	Mean MAE: 6.37°

Table 2: MAE between Predicted MoCap and Observed MoCap Across 10 Subjects

Exercise	MAE Knee R (°)	MAE Knee L (°)	MAE Ankle R (°)	MAE Ankle L (°)	MAE Hip Flexion R (°)	MAE Hip Flexion L (°)	Mean MAE Across Joints (°)
Backward Lunge	4.43	4.05	5.48	5.75	5.90	5.43	5.17
Curtsy Lunge	5.13	4.59	5.39	6.52	6.27	5.83	5.62
Forward Lunge	4.78	4.62	5.68	5.35	4.34	4.18	4.82
Goblet Squat	3.96	3.67	2.92	2.95	4.76	4.32	3.76
Hamstring Curl	4.24	4.14	3.91	6.23	3.29	3.30	4.18
Lateral Lunge	4.45	4.26	4.32	4.85	5.27	6.06	4.87
Plie Squat	4.40	3.29	3.55	3.26	5.56	5.17	4.20
Squat	3.49	3.64	3.42	4.72	6.60	6.99	4.81
StepUp	3.70	3.45	3.16	3.66	3.80	3.67	3.57
VLegRaise	5.01	4.45	3.75	3.85	4.63	4.84	4.42
Mean MAE Across Exercises	4.36	4.02	4.16	4.71	5.04	4.98	Mean MAE: 4.54°

Conclusions

Our model delivers a significant improvement in accuracy over the current OpenCap outputs. As evaluated by the standard identified by the research team behind OpenCap, their model currently fails to meet the acceptable error range for 25% (15/60) of joint angles across 10 exercises. However, by applying our model on top of the OpenCap platform, its outputs can be brought within acceptable limits for all motions tested.

Future Work

In the future, the research team hopes to confirm the generalizability of these findings to exercises and demographics not covered in this study and expand the scope of this research to upper body exercises and full-body exercises.

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References

[1] S. D. Uhlrich et al., "OpenCap: Human movement dynamics from smartphone videos," PLOS Computational Biology, vol. 19, no. 10, Oct. 2023. doi:10.1371/journal.pcbi.1011462

[2] A. Falisse, S. D. Uhlrich, A. S. Chaudhari, J. L. Hicks, and S. L. Delp, "Marker Data Enhancement for Markerless Motion Capture," IEEE Transactions on Biomedical Engineering, pp. 1–10, Jan. 2025. doi:10.1109/tbme.2025.3530848

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