From Inertial Motion Capture to Ground Reaction Forces & Moments

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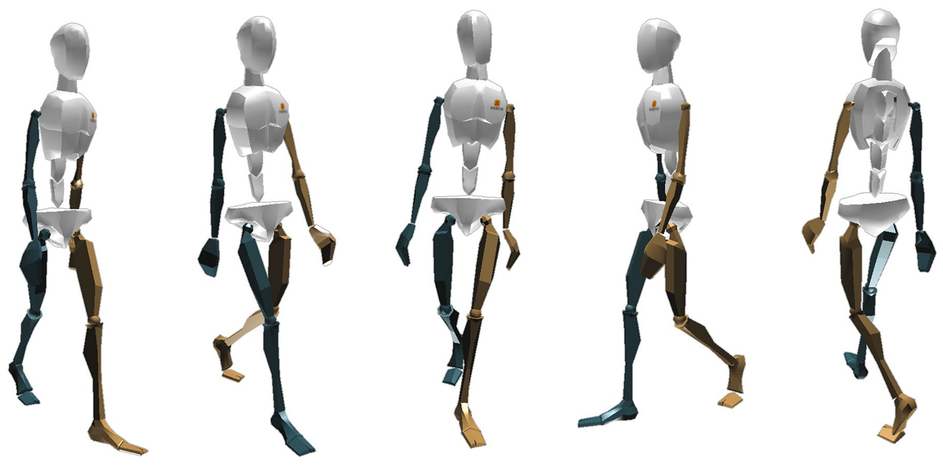
Introduction

- Ground Reaction Forces & Moments (GRF&M) are important inputs in biomechanical analysis to derive joint loading.
- Conventional assessment of GRF&M requires a laboratory setting, equipped with force plates.
- Recent methods in biomechanics allow estimation of GRF&M only from optical motion capture [1].
- Inertial motion capture provides a robust alternative to optical motion capture which can be used in ambulatory settings [2].

Objective

- To predict the GRF&M during walking using only kinematics from inertial motion capture.

Methods



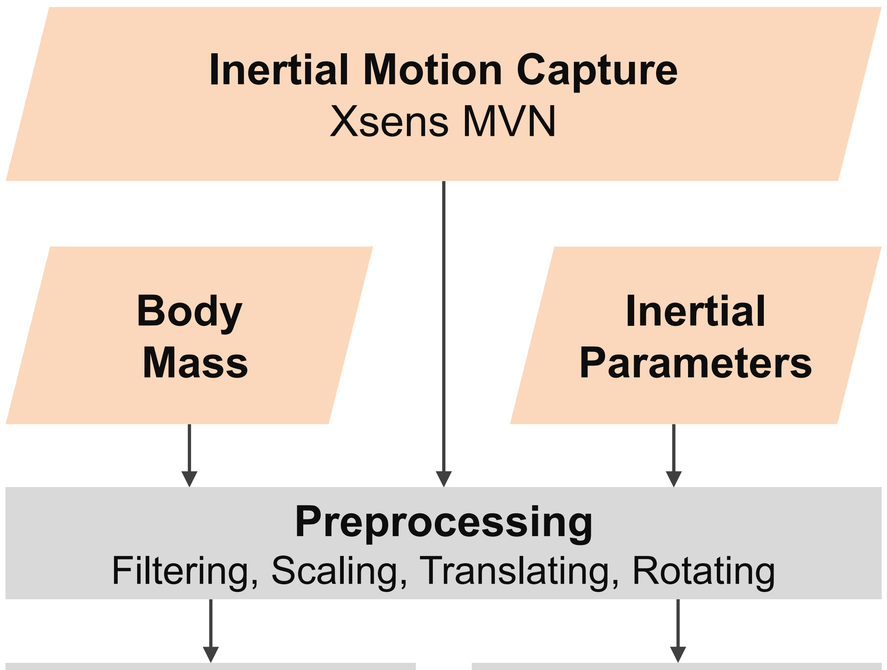


Figure 1: Flow diagram of the algorithm developed to predict ground reaction forces & moments during walking from inertial motion capture and anthropometric input.

Results

- Excellent correlations for anterior, vertical & sagittal and strong correlations for lateral, frontal & transverse GRF&M.
- Low rRMSE (<10%) for anterior & vertical and moderate rRMSE (<20%) for lateral & sagittal GRF&M.

Table 1: Comparison of estimated versus measured ground reaction forces (GRF) and moments (GRM) using Pearson's correlation coefficient (ρ), absolute (RMSE) and relative (rRMSE) root mean square errors, averaged for all steps within the gait cycle.

		ρ	RMSE (N/kg or Nm/kg*m)	rRMSE (%)
GRF	**Anterior**	0.953	0.33 (0.09)	8.03 (2.05)
	Lateral	0.852	0.18 (0.04)	15.24 (4.70)
	Vertical	0.991	0.69 (0.36)	5.93 (3.13)
GRM	**Frontal**	0.726	0.10 (0.04)	40.22 (18.68)
	Sagittal	0.903	0.15 (0.05)	14.97 (3.84)
	Transverse	0.862	0.02 (0.01)	21.02 (6.42)

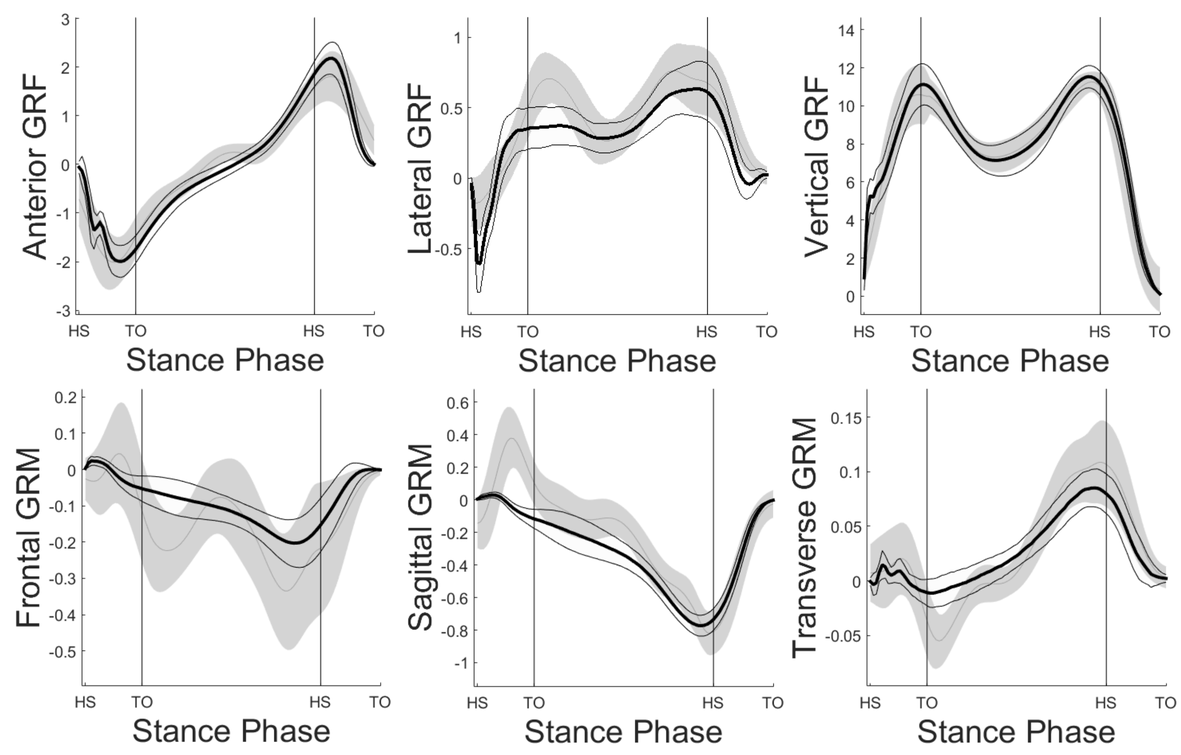


Figure 2: Comparison of the ground reaction forces (GRF) and moments (GRM) estimated using the proposed method (mean (thin grey line) ± SD (shaded area)) versus force plate measurements (mean (thick black line) ± SD (thin black lines)). GRF is normalized to body weight and GRM normalized to body weight times height.

Conclusions

- First-ever study to predict 3D GRF&M using only inertial measurement units.
- GRF&M predictions provide strong to excellent agreement and performance is comparable to optical-based prediction.
- The setup enables estimation of net joint moments using segment kinematics available from inertial motion capture.
- Future research should focus on development of movement independent & real-time solutions, as well as evaluating the clinical applicability of the technique.

References

[1] L. Ren, R. K. Jones, and D. Howard, "Whole body inverse dynamics over a complete gait cycle based only on measured kinematics," *J. Biomech.*, vol. 41, no. 12, pp. 2750–2759, 2008.
[2] D. Roetenberg, H. Luinge, and P. Slycke, "Xsens MVN : Full 6DOF Human Motion Tracking Using Miniature Inertial Sensors," July 2015, pp. 1–9, 2013.

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