GaitQuest: Markerless Gait Analysis from an Observer-Worn Head-Mounted Display

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ECCV 2026 | MALMÖ | SEPT 8–12

Introduction

Human Mesh Recovery (HMR) methods, such as CameraHMR (Patel & Black, 2024), enable markerless 3D motion capture from monocular RGB images.
However, existing approaches are mainly validated with static cameras.
GaitQuest extends HMR to a moving observer-worn camera, allowing an observer to freely follow participants during gait assessment out of the laboratory.

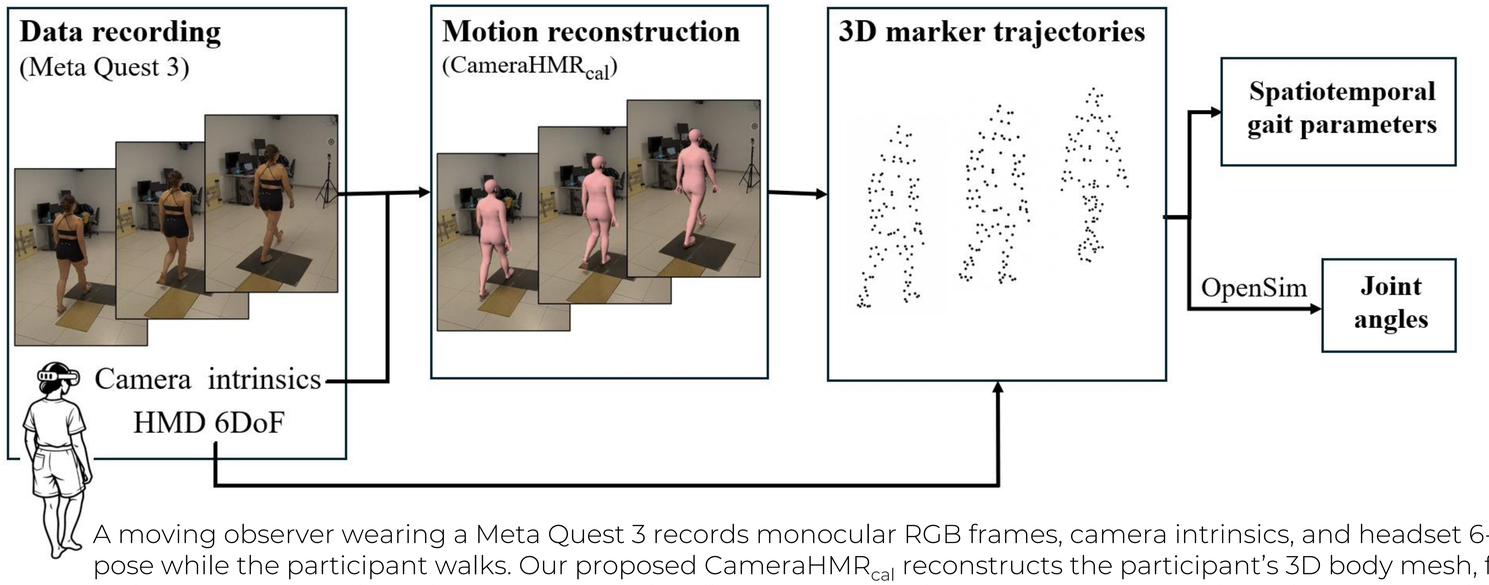
Key idea

CameraHMR estimates the focal length per frame. CameraHMR$_{cal}$ instead feeds the device-calibrated fx, fy, cx, cy directly to the model. Then, we compose the camera-to-headset extrinsics with the per-frame 6-DoF headset pose to recover the mesh in world coordinates.

Validation against Vicon

8 participants, 8 spatiotemporal gait parameters,
6 lower-limb joint angles

The GaitQuest pipeline



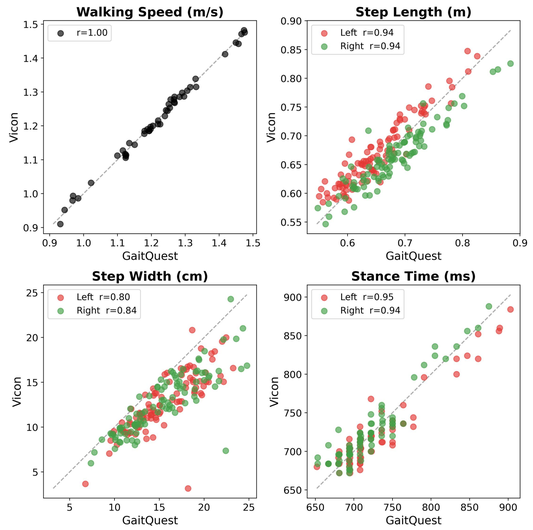
A moving observer wearing a Meta Quest 3 records monocular RGB frames, camera intrinsics, and headset 6-DoF pose while the participant walks. Our proposed CameraHMR$_{cal}$ reconstructs the participant's 3D body mesh, from which 3D marker trajectories are extracted in a fixed world coordinate system. These trajectories are used directly to compute spatiotemporal gait parameters and as input to OpenSim to compute joint angles.

Results: spatiotemporal gait parameters

- CameraHMR$_{cal}$ improves 3D spatial reconstruction
- CameraHMR$_{cal}$ yields accurate gait parameters
- CameraHMR$_{cal}$ is robust to occlusion

MAE (mean ± SD across participants)

Parameter	CameraHMR	CameraHMR$_{cal}$
Walking speed (m/s)	0.04 ± 0.02	**0.01 ± 0.00**
Stride length (cm)	13.5 ± 1.9	**1.5 ± 0.3**
Step length (cm)	12.7 ± 1.2	**2.3 ± 0.6**
Step width (cm)	2.6 ± 1.4	2.7 ± 1.5
Stride time (ms)	10 ± 1	**9 ± 2**
Stance time (ms)	16 ± 4	**15 ± 3**
Swing time (ms)	14 ± 4	14 ± 4
Double support (ms)	15 ± 4	15 ± 4



Results: joint angles

- Joint angles are computed from the relative configuration of body segments and are therefore insensitive to global scale error → CameraHMR$_{cal}$ does not improve joint angles
- Best results for hip and knee flexion angles, with r = 0.97. However, MAEs exceed 5°

CameraHMR$_{cal}$	MAE (°)	Pearson r
Hip flex/ext	5.6 ± 2.7	0.97 ± 0.03
Hip abd/add	5.1 ± 1.0	0.65 ± 0.27
Hip int/ext rot	8.5 ± 1.9	0.11 ± 0.25
Knee flex/ext	7.6 ± 2.6	0.97 ± 0.02
Ankle dorsi/plantar	11.6 ± 2.0	0.45 ± 0.08
Pelvis tilt	2.9 ± 1.2	0.16 ± 0.31