PS3.1

Evaluation of an optimization method for measuring treadmill walking motion using IMUs

Anirudh Bhateja[1], *Ted Yeung*[2], *Thor Besier*[2], *Benjamin Fregly*[1]

1 *Rice University, Mechanical Engineering, Houston, United States*

2 *The University of Auckland, Auckland, New Zealand*

Inertial measurement units (IMUs) could provide an attractive alternative to video motion capture systems for measuring walking in a non-laboratory setting. This study applied an optimization method to an 18-DOF lower body model to convert synthetic IMU data into corresponding joint angles.

Experimental video motion capture and IMU data were collected from a single subject who performed treadmill walking at a self-selected speed. OpenSim model scaling [1,2] was performed to scale a generic 3D OpenSim model [3] and attach dynamic markers and IMUs to the pelvis (6 DOFs) and lower body segments (6 DOFs per leg). Next, OpenSim inverse kinematics was performed to calculate pelvis and lower body joint angles as well as corresponding synthetic IMU measurements. Finally, synthetic noise was added to the synthetic IMU data to emulate actual IMU data. For the treadmill walking trial lasting over 30 seconds, pelvis and lower body joint angles were recovered from the noisy synthetic IMU data using a nonlinear least squares optimization method implemented in MATLAB. For each time frame, the optimization adjusted the kinematic model's joint positions, velocities, and accelerations to minimize errors between model and synthetic IMU data and between model and implicitly integrated joint positions and velocities. The actual values of the joint angles and its derivatives were used to set the initial states of the model.

The optimization method tracked the joint positions well for the duration of the treadmill walking trial (average RMS errors of < 2 mm for translations and < 0.1 deg for rotations). Thus, the optimization method could entrain the kinematic model to the natural system dynamics. The rotations were tracked better than were the translations since the noisy synthetic accelerometer data led to greater errors that could be corrected by the noisy synthetic gyroscope measurements. The optimization method was relatively insensitive to the selected cost function weights for position, velocity, and acceleration errors and produced fairly accurate and robust joint angle estimates but at the cost of high computation time. Work is under way to repeat the evaluation using actual IMU data synchronized with motion capture data.

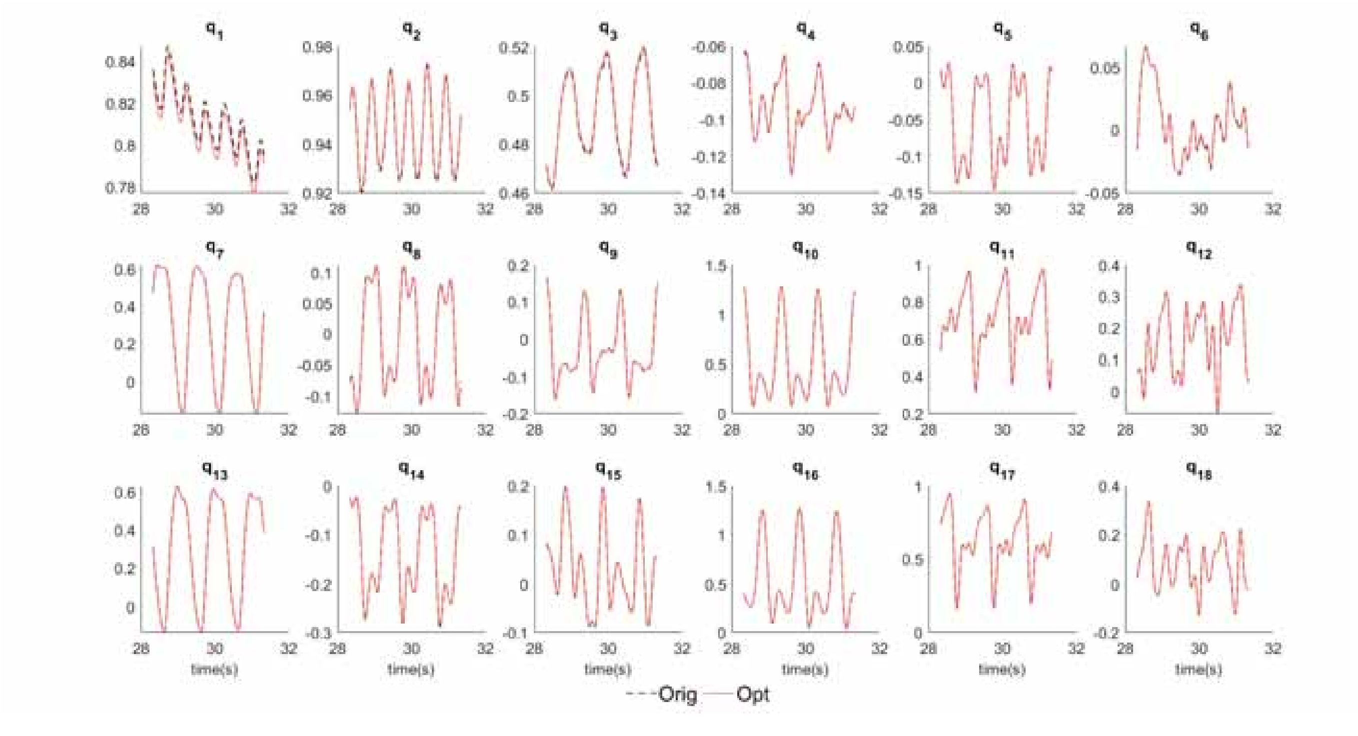

Figure caption: Optimization estimates for generalized coordinates during the last 3 seconds of treadmill walking. q_1-q_3 are pelvis translations (in meters), q_4-q_6 are pelvis rotations (in radians), q_7-q_12 are right leg joint angles (in radians), q_13-q_18 are left leg joint angles (in radians).

Acknowledgments: This work was funded by the National Science Foundation under award number 1805896.

References:

Delp, S.L., et al. IEEE Transactions on Biomedical Engineering, vol 55, pp 1940-1950. (2007)
Seth, A, et al. PLoS Computational Biology, 14(7). (2018)
Rajagopal, Apoorva, et al. IEEE Transactions on Biomedical Engineering 63.10 (2016): 2068-2079. (2016)